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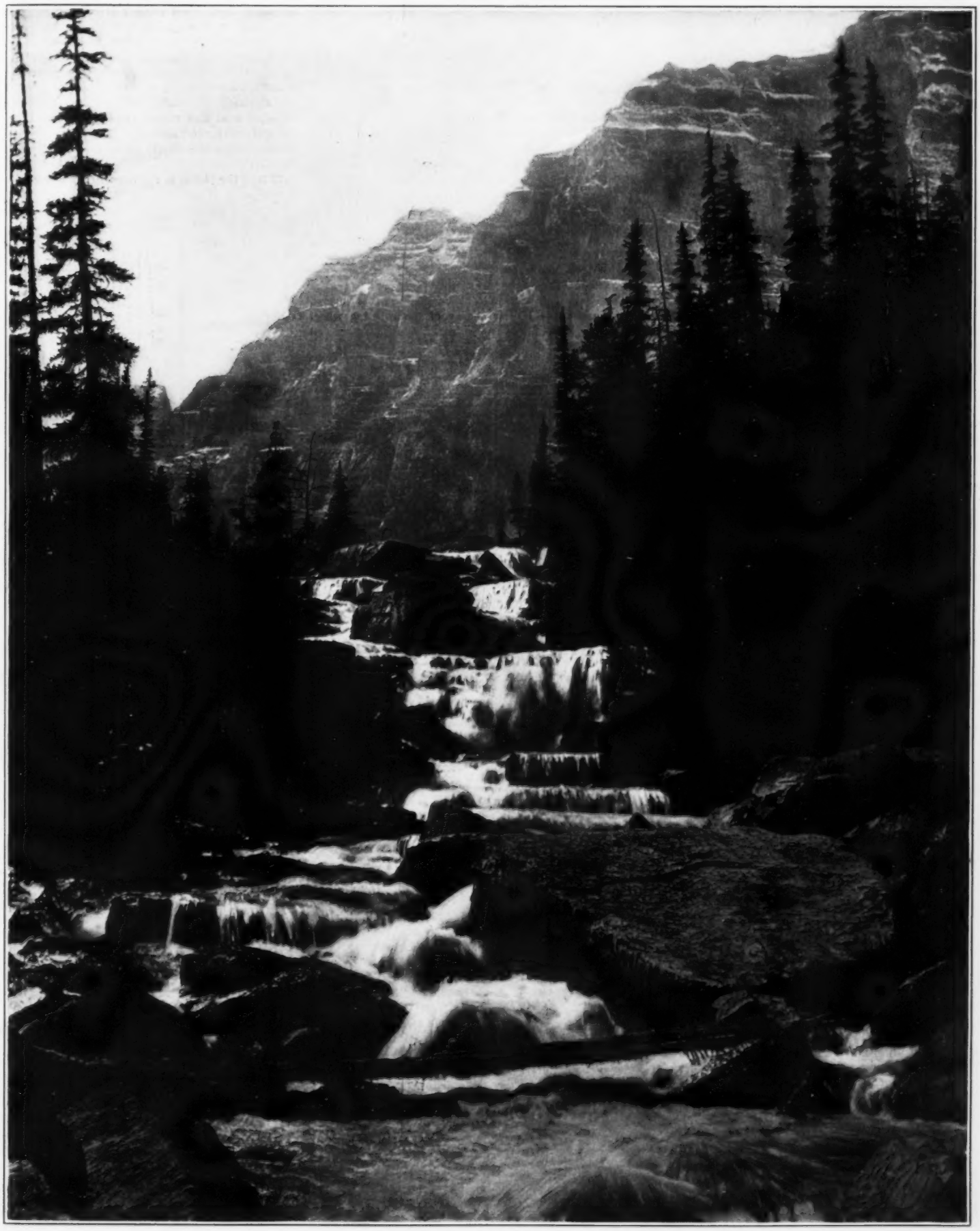

Giant Steps, in Paradise Valley.—A bit of Canadian scenery.

CANADA.—[See page 40.]

Vibrations, Waves and Resonance—I*

The General Principles Underlying Wave Motions

By J. Erskine-Murray, D.Sc., F.R.S.E., M.I.E.E.

VIBRATIONS.

THE extent of the field covered by the subject of these lectures is so vast that it would be quite impossible for me to describe in detail even one of the many types of periodic motions which exist. I shall not attempt to do so, but shall try to explain to you the general principles underlying all wave motions, and describe only such particular cases as appear to illustrate these principles most simply and directly. You will understand, therefore, that when I have demonstrated any property of vibrations or wave motions by experiment or otherwise, the property is in general a quality of all such motions whether material or electrical, and, if the nature of the vibrator or of the medium in which the wave motion takes place be specified, the results obtained in the demonstration are applicable, *mutatis mutandis*, in all cases. I shall, in fact, treat the subject from the point of view of natural philosophy, which deals with the laws of the natural world, rather than that of physics, which is mainly concerned with the description of phenomena.

A vibration is a to-and-fro motion. It is called periodic if it is repeated in equal successive periods of time, and this even if the repetitions are only similar in character though not in magnitude. The *period* of a vibration is, therefore, the time of one complete vibration—there and back again—and its *frequency* is the number of complete vibrations in one unit of time.

The frequencies of the vibrations which concern humanity range from about thirty million-million-million per second in the case of the gamma rays given out by a radio-active substance, to one in twenty-six thousand years, which is the frequency of the motion known as the precession of the equinoxes. Briefly, the result of this latter is that thirteen thousand years hence midwinter will be in June and midsummer in December in the northern hemisphere. And here it suggests itself that if we can "save" an hour of daylight by "merely turning on the clock," might we not "save" a summer by merely altering the calendar?

Between these limits of frequency, the greater of which is twenty-five million-million-million-million-million times the less, lie the frequencies of motions with which we have to deal. These run through X-rays; ultra violet and visible light; heat waves; waves which are recognizable by what are known as electrical actions and are therefore called electric waves, whether fast or slow, conducted or free; the vibrations of sound; of the heart and respiration; of machinery and structures; of ocean waves and tides, and of the earth itself—a wonderful list, almost every item of which is present with us at all times.

It is hardly astonishing that rhythmic motions should be of so much interest to humanity, for the life of each of us is wholly dependent on two vibrations. If the heart or lungs cease their regular periodic motions we cease to live, and even small changes of frequency or amplitude may be of serious moment. Music, dancing, the beat of the drum and the regular tramp of marching troops are all pleasant, for our hearts respond to the rhythmic stimulus, and even "carriage exercise," with its comparatively gentle vibrations, is often of value to health.

Although the variety is apparently so great, there are in reality only two kinds of physical vibration—one in which the thing moved is electric, and the other in which it is ordinary, or ponderable, matter. In both cases the energy associated with the material moved is converted from energy of stress into energy of motion, and back again to energy of stress twice in each period of the vibration. In this pendulum, for instance, the energy of the gravitational stress between the bob and the world is converted into kinetic energy as the bob swings down toward the world, and is reconverted into energy of stress as it rises again on the other side. On the return journey, completing the period, the same conversion and reversion takes place. In these other oscillators which I show you the stress is that of a strained elastic solid or fluid, but the cycle of energy and motional changes is still the same.

In all cases the primary condition for the possibility of a vibration is that the body or system, to use a more general term, must have a position of stable equilibrium—that is to say, one from which to move it in any direction requires that the work done on it should be converted into energy of stress. The pendulum, for instance, is stable in its lowest position, and an electric vibrator when it has uniform potential throughout. There is a secondary condition which must be fulfilled if the vibration is to be periodic, and this is that the energy of motion must not all be converted into molecular motions, by friction or otherwise, by the time the system first reaches its position of equilibrium. If, for instance, the pendulum be moving in a sticky fluid such as treacle, it may come quite to rest on its first arrival at the lowest point of its course, or rather it may take an infinite time to get there, all its energy of motion being used up in molecular friction in the liquid and so converted into heat.

I have another vibrator here in which gravity plays no part, since its motion is entirely in a horizontal plane, neither rising nor falling. It consists of a cast-iron wheel threaded firmly on to a vertical strip of clock spring, the latter being fixed, at its upper and lower ends, to a rigid frame. If I turn the wheel and let go, it swings round to its position of equilibrium, passes it, stops and reverses its motion, and continues to rotate to and fro with slowly decreasing motions. Here the potential energy of the elastic stress in the steel strip, which is twisted when the wheel is turned, is converted into kinetic energy of the rotating wheel in the first quarter period, reconverted into potential in the second quarter, and so on.

All the while, however, some small proportion of the energy is being lost in friction, or rather is being converted into the energy of molecular vibrations in heating the steel strip and the surrounding air. This is so entirely general a condition of all physical motions that one may state it as a principle, thus: In every physical motion of greater than molecular dimensions, whether of ponderable matter or of electricity, there is a continuous conversion of energy into the energy of molecular vibrations. Thus all friction produces heat, and no motion of real matter is perfectly frictionless nor is any electric circuit entirely without resistance. If no other proof existed of the molecular nature of matter we should still have one here which would be almost incontrovertible, for the vibrators which produce short waves must themselves be small.

Returning to the torsional vibrator, you can see that its rate of vibration depends mainly on its inertia and on the restoring force of the spring, for by placing an additional mass on the wheel the rate of vibration becomes visibly slower, while the same result is observed if a weaker spring is used. Frictional resistance also slows the motion, but, unlike added inertia, it produces the further effect of rapidly damping it out altogether.

Three factors such as these determine the nature of all free vibrations whether mechanical or electrical. Thus, in an electrical vibrator, having no mechanical motion, the electric stress in the dielectric produces a current in the conductor, which in turn generates magnetic force around it, thus delaying the growth of the current, but temporarily maintaining it when grown, just as inertia does in the torsional vibrator. Electric resistance, like friction, retards the motion throughout, and finally converts into heat all the energy that has not been radiated as electric waves.

We may make some sort of mental picture of what goes on in an electric oscillator during its action by translating into terms of ordinary materials the electrical quantities concerned. A non-conductor or dielectric, for instance, is equivalent to an elastic but incompressible jelly or mass of india rubber, while a conductor is a cavity in the jelly filled with an incompressible liquid. The conducting plates of a condenser may thus be represented by two cavities filled with water in a great mass of jelly and separated from one another only by a thin wall. I say a great mass because the air surrounding them is, like the glass between the plates, a non-conductor. The plates are, therefore, two isolated cavities filled with water in a mass of jelly. Suppose now that I drive a small tunnel, also filled with water, from one cavity to the other, and in this tunnel place a pump or piston by means of which I can take water from the one and drive it into the other. As I do so, taking water from the left-hand cavity and driving it into the right-hand one, I cause the latter to swell and the former to contract, and since the thin wall of jelly between the cavities has little rigidity, it is here that the greatest swelling and contraction take place. The wall bulges toward the left-hand cavity, and, of course, the jelly forming it is strained. Now the wall represents the dielectric of the condenser, the increase of volume of the right-hand cavity is the positive charge, and the equal decrease of volume of the left hand is the negative charge on the other plate of the condenser. This picture is correct in two important respects at least; first, it shows that the amount of charge which a condenser will hold is not, like the capacity of a pint pot, simply defined by its dimensions, but is also dependent on the pressure or voltage between its plates and on the stiffness of the dielectric; the electrical capacity has, therefore, to be defined as the charge at unit electrical pressure; second, it shows the potential energy stored, not in the charges themselves, but in the elastic stress in the dielectric. (See Fig. 1.)

If now the piston in the tunnel connecting the cavities

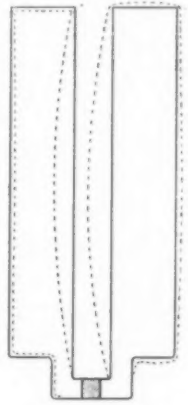

Fig. 1.

be suddenly annihilated, the tension in the bulging wall will tend to drive the excess liquid in the right-hand cavity back through the tunnel toward the left hand, and this pressure will continue to act until the elastic strain is entirely relaxed and the cavities return to their original sizes. At this moment, however, the water will be flowing rapidly through the tunnel from right to left, and, although there is no longer a pressure driving it, it will continue to do so on account of its inertia even after the position of equilibrium has been passed. Thus the left-hand cavity will be charged to a high or positive pressure and a negative charge will be produced in the right-hand one. When all the energy of motion of the water has been converted into potential energy in the elastic wall, now bulging toward the right, the motion will cease, the flow will reverse, and the operation will recommence in the opposite direction. These reversals of flow will continue, though becoming gradually less and less, until all the energy originally stored in the stretched wall has been converted into heat through friction or radiated throughout the mass of jelly as elastic waves.

This picture apparently fails in one respect only to represent an elastic oscillation, and that is in the representation of the inductance of the circuit by the inertia of the water. In the electric case the kinetic energy of the current is not in the conductor itself, but is located as magnetic stress in the medium surrounding it, while inertia we usually think of as a property located entirely in the mass itself. Who knows, however, that this is so? We cannot appreciate inertia in a single body by itself. Even if we consider a solitary body in rotation we have to imagine it to be divided into two parts between which there is a stress before we recognize its inertia. Thus there must always be two bodies between which the force can act by which we know of the existence of mass, and if there must be two bodies we at once realize that the property which we supposed was wholly located in the body may in reality be just as likely a property of the medium surrounding them such that their relative motion through it causes a storage of energy in it and not solely in the bodies themselves. If so, our picture may be more complete than it at first appears; but in any case it is a good and serviceable representation, equally true to nature whatever theory of the ultimate constitution of electricity may be adopted.

The vibrations which I have so far shown you have

*Cantor Lectures before the Royal Society of Arts. Republished from the *Journal* of the Society.

been simple and more or less exactly of the type known as "simple harmonic." Such vibrations, however, are not as common in nature as the more complex kinds; but, luckily for us, Fourier discovered that every complex vibration could be analyzed into a group of simple harmonic ones, and on the other hand, that by superposing properly chosen simple vibrations on one another any desired complex vibration could be built up. The simple harmonic or sine wave type of vibration is, therefore, not only simple, but is also fundamental. The vibrator which I now show you in motion consists of two elements, each being formed by a helical spring with a weight attached to it (Fig. 2). If the two are

Fig. 2.

hung up in series from a firm support, that is to say, in the order counting downward, of support, spring, weight, spring, weight, you see that by giving impulses in opposite direction to the upper and lower weights we obtain a curiously jerky, complex motion of the lower weight as it rises and falls. The fact is that we have superposed the vibrations of the parts on the slower vibration of the system as a whole, and the movement of the lower weight, though still periodic, is no longer a simple harmonic vibration.

Complex vibrations of this type are most directly interesting to every human being, though he or she may not be aware of it, since it is through their character, and in no other way, that speech is articulate and that one speech sound is distinguishable from another. The sound "oo," for instance, is merely a smooth vibration, while "o" is a compound of the same sound with a vibration twice as fast, i. e., the octave above. "Ah" contains also the third harmonic, or fifth above the octave, and "e" is a still more jerky vibration. All other articulate sounds are defined in the same way, each by its component simple vibrations, and each can be represented by a single wavy line having a definite character of its own. If the pitch on which the sound is spoken is higher or lower, the rate of vibration becomes greater or less, but its character is unchanged.

I move my hand smoothly to and fro. If I could do so at something over thirty times per second you would hear the sound "oo;" I move it again to and fro, but this time in a series of small jerks. If it were fast enough you would hear the sound "e." Every sound in every language could be produced in this way, if one could only move one's hand sufficiently rapidly and give its motion exactly the proper form.

About fourteen years ago, when lecturing on physics in University College, Nottingham, I constructed a little instrument which will show you the actual forms of the vibrations of various sounds. A piece of thin sheet india rubber is stretched over the end of a short hollow cylinder about 2 inches in diameter. On the center of the india rubber a small circle of paper is stuck in order to give a little greater stiffness, and to the paper is attached by a small india rubber hinge, a rod of wood about five millimeters long and one millimeter or less in diameter. The top of the rod is hinged to one edge of a little mirror, which lies parallel to the membrane and is mounted on a fine needle pivoted at both ends and borne by supports attached to the cylinder or mouthpiece. Holding this little instrument, which I have named the phonoscope, in my hand, I direct it so that a spot of light is reflected from its mirror on the screen. If I speak to the membrane it vibrates and the spot of light becomes a short vertical line, and if at the same time I turn the phonoscope to and fro this line is stretched out into a beautiful wavy curve, which changes its form with every inflection of the voice. If I were to play different musical instruments to the phonoscope you would learn to recognize that the timber of each is in reality defined only by the character of its vibration curve; that the flute gives a smooth wave, while that of the violin is complex and full of higher harmonics. Even the combined sounds of a whole orchestra make up but one wave curve—a very complex one, but still quite definite and capable of analysis.

Fascinating as is the study of the forms of musical and articulate sounds, we cannot at present spend more time on it, but must get on to other types of vibration. The earth itself, for instance, is in a constant state of tremor, sometimes more and sometimes less, but never quite at rest. Its vibrations are usually too slow to be audible, but occasionally there are rumbling sounds and dull thuds such as I heard during a small earthquake in the Midlands some years ago. It was like the passage of several heavy traction engines over a causewayed street close by. Quite thirty years ago I was taken to see an earthquake recorder in the little town of Comrie in Perthshire. It was a very simple affair, just a thin lath of wood held in a horizontal position by a fixture at one end, and placed so that the maximum movement of the free end was recorded by the displacement of a straw pointer on a dial. If the earth rose suddenly, the fixed end of the lath and the dial both rose with it, but the free end lagged behind and pushed the straw round to a new position, where it stayed and thus gave a record of the magnitude of the shock. The instrument was, I think, devised by the local baker. Present-day seismographs depend on the same or similar principles, but have been made to give continuous records, instead of merely an indication of the maximum vibration. A large mass is fixed to the end of a spring or forms the bob of a nearly unstable pendulum. As the earth shakes, the bob, owing to its great inertia, remains almost unmoved and the relative motion of earth and bob is recorded photographically, or if the ground is tilted up the pendulum comes over and shows the slope.

I have here a rough model on the same principle, which will show you the action. A strip of metal is fixed horizontally at one end, and from its other end two short parallel threads run to adjacent fixed points on the table. A small mirror is stuck on to the threads and reflects a beam of light onto the ceiling. If I jump on the floor some yards away, you notice that the spot of light vibrates, showing the transmission of the vibration through floor and lecture table to the seismometer.

The reason why the early seismometer was found at Comrie is that a great geological fault, which stretches from the Firth of Clyde to near Aberdeen, runs through the town. On the southeastern side of the fault lie the comparatively modern carboniferous strata, while to the northwest of it the ancient Silurian rocks are thrust up thousands of feet; the fault is in fact a great crack or discontinuity in the earth's crust. Now, as the earth contracts its crust becomes strained, and from time to time the stress causes a sudden, though small, slip at the fault itself, one side rising and the other falling to accommodate themselves to the growing pressure. This is an earthquake, and the vibrations caused by the sudden motion spread out through the neighboring rocks.

To show you how frequently these tremblings occur, I may tell you a story told me by the late Prof. Milne some years ago. It was at the time when the Psychical Research Society was investigating household ghosts, and, as you know, there are many of these in old Scottish houses. Often nothing is seen, but curious noises are heard, locked doors open, and the dwellers in the houses are aware that something uncanny is happening. The society asked Prof. Milne to take one of his seismographs to various houses, and it was proved that in several cases the ghost was in fact a seismic tremor, too slight to be recognized as an earthquake, but quite sufficient to do the work of the ghost.

Volcanic explosions sometimes produce extraordinarily powerful vibrations. When the mountain of Krakatoa, in the East Indies, was rent to pieces by the steam pressure in the cavities below its crater, the pressure wave produced in the air was so great that it was heard as a loud sound at a distance of more than fifteen hundred miles, and traveled eight times round the earth before it became too weak to affect a registering barometer. The energy and suddenness of the explosion must have been very great, for although the firing of great guns has been heard in the present war up to distances of more than three hundred miles, it is equally true that thunder rarely carries as much as twenty.

Instruments have now been constructed which register the vibrations of all kinds of structures, and many interesting results have been obtained by using them in buildings and on ships and railway trains. It has been shown, for instance, that short and sharp vibrations of ten or more to the second are much more exhausting to the human frame than those of longer and smoother period. The natural vibration of a torpedo-boat destroyer is about three per second, while an old third-class carriage makes twenty or thirty very irregular jerks in the same time.

All the vibrations which we have considered so far have had what is called a "static" restoring force; in some cases this has been gravitational, and in others elastic or electric. Now, however, I shall show you two cases in which this restoring force is actually and obviously due to motion. Here is a small gyrostat—just a heavy wheel pivoted inside a ring-shaped frame. I cause it to spin rapidly and set it on the table. You notice that it stands up, supporting itself on the edge of the ring, apparently in defiance of gravity. It appears to be held up, as if in virtue of its motion it had a grip on something that we cannot see. I strike it, and it vibrates as if supported by some intangible elastic solid. Here the restoring force is not static, but is due to the motion of the mass constituting the wheel. May it be that, as I suggested when describing the oscillations of the liquid in a model electric condenser, the rotation of the wheel does actually give it a grip on some all-pervading medium? If so, we should expect that two rotating bodies would react upon another across space in virtue of their rotations—a notion which may be proved or disproved by experiment, or perhaps by deduction from planetary astronomy.

One most interesting way of looking at gyrostatic phenomena is to consider them in relation to gravitational force. Thus, for instance, a spinning-top when at rest lies with its center of gravity as low as possible, but when spinning it rises till its center of gravity is as high as it can get. If I strike the top lightly when spinning it nods, but rises again to its steady position; its rotation has thus changed a position of unstable equilibrium into one of stable equilibrium about which it can vibrate. The spinning-top has thus the curious property that in a field of gravitational force it places itself so that the gravitational potential energy is a maximum, the line from its point of support through its center of gravity being parallel to the gravitational force and directed away from the earth. It would be very interesting to know whether similar effects are obtainable in uniform fields of force other than gravitational; whether, for instance, an electric or magnetic gyrostat could be constructed which would tend to get into a position of *maximum* potential energy when rotating in an electric or magnetic field.

Now I shall show you a vibrator which really is very strange, for it consists merely of air in air, and yet is a distinct entity, a body capable of vibration, and can travel through the atmosphere of which it forms, and yet does not form, a part. Here is a large box full of air, which has in front an elliptical opening and at the back a hinged flap like a bellows. Mixed with the air, to make its motion visible, there is some smoke, or the cloud of fine crystals obtained by mixing gaseous hydrochloric acid and ammonia. I slap the back of the box, and a puff comes out at the front which quickly takes shape as a definite and cleanly formed ring, not circular, but changing rapidly from an ellipse with its greatest length vertical to one which has its greatest length in a horizontal direction, and *vice versa*. Out of air I have in fact created a vibrator having apparently all the properties of an elastic solid. If I could make it vibrate fast enough you would hear a musical tone—a sound produced by an unenclosed mass of air vibrating in air.

It has occurred to me since first I saw these rings produced in Lord Kelvin's class-room that this experiment may not unlikely have been the origin of his vortex theory of matter. A vortex ring when circular is beautiful, but an elliptical one is so obviously a material thing with elastic properties of its own that, after seeing it, the temptation to make use of it as a possible ultimate basis for a theory of matter must have been irresistible to a mind like Kelvin's.

(To be continued.)

Copper Deposits in the Arctic Regions

According to the *Electrician*, Dr. R. M. Anderson, who has recently returned from an inspection of Arctic copper deposits for the Canadian Government, reports that vast areas rich in copper occur near Coronation Gulf and Bathurst Inlet, some of the seams in the lava being filled with pure copper. It is possible that these deposits could be rendered accessible by building a railroad from the Mackenzie River, which is navigable for five months in the year, to Great Bear Lake, and a further railroad from thence onward.

Poisoned Arrows*

The Venoms Used in Their Manufacture, and Their Action

Poisoned arrows are used by many savage tribes in war and, to a still greater extent, in hunting. Much light has been thrown on this hitherto mysterious subject by the researches of MM. Perrot and Vogt.

Arrow poisons are of great variety, including animal venoms, products of putrefaction and bacterial cultures, in addition to plant juices, which are most commonly employed. All arrow poisons act very quickly, arresting the heart's beat, provoking violent convulsions, or paralyzing the motor nerves.

In Africa a great many plants are used, especially various species of *Strophantus*, *Acocanthera* and the group of desert plants. *Strophantus* is employed throughout western Africa, from Guinea to Angola, and also in Zambesi, on the east coast. In Cameroon and Gaboon the *Strophantus* poison is mixed with other substances, such as snakes' heads, toads, milky plant juices, putrefied blood, etc. The method of preparing the poison varies with the locality. In general, the finely chopped fruits of *Strophantus* are boiled in water for 24 to 30 hours, and the liquor is boiled down to a paste into which the iron arrow tips are dipped. The tips are then dried in the sun. If they are not used within a few months they must be treated again, because the poisonous coating gradually scales off and also loses its virulence. The poison acts very violently, and kills a man in 10 or 15 minutes. During the first few minutes the victim does not appear to suffer. Then come convulsions, accompanied by agonized cries, and followed by a few minutes of calm, which end in death.

The *Acocanthera*, which furnishes the arrow poison of the Somali tribes, is a shrub on which animals browse with impunity. The arrow poison is extracted from the root, which is boiled in water for hours or even days, until the extract has the consistency of pitch. Some tribes add snakes' heads and other things which do not appear to increase the virulence greatly. The maker of the poison tests its strength by bringing a little of it in contact with the lower end of a little stream of blood trickling down his arm from a self-inflicted scratch. The poison is well made if it coagulates the blood on contact and the coagulation advances up the stream. The arrow tips are coated with the poison and wrapped in strips of goatskin or vegetable fibers, which are not removed until the instant of use. An accidental prick with a poisoned arrow is treated by promptly making a deep incision around the wound and cutting out the infected part. A little of the poison itself, placed on the tongue, is used as an antidote. For this purpose the Somalis, at least in war, always carry some of the poison. The principal use of the poison, however, is in ostrich hunting. The hunters, armed with very small bows, lurk in tall grass, among which they have scattered the seeds preferred by the ostrich. The bird approaches without distrust and when quite near is shot with a short arrow having a poisoned iron tip of triangular section with two lateral wings which hold it securely in the wound. The wounded ostrich, not pursued, retreats quietly but soon falls, killed or paralyzed by the poison.

The principal desert plants are huge Euphorbias, which closely resemble Cactus, and yield a milky juice that is only slightly poisonous.

The arrow poisons of Asia and Oceanica may be classified in five principal groups: Anemones, Aconites, Ipohs, cadaveric poisons and microbial poisons.

Various species of *Anemone* are used, in default of anything better, in the extreme north of Asia, where the flora is very poor. The wound instantly becomes livid and begins to swell, and death ensues within two days, unless the poison is extracted by sucking.

The Aconite, particularly *Aconitum ferox*, is the favorite Asiatic arrow poison, and is used in India, Assam, Burma, and Yunnan. It is employed chiefly in hunting elephants and buffaloes. The former die in a few hours and the latter almost instantaneously. The wounded part is cut out and the rest of the flesh is eaten with impunity.

The Ipohs are complex poisons used in Malacca and the Malay Archipelago. Usually the principal ingredient is the milky juice of *Antiaris toxicaria*, or an extract of a species of *Strychnos*, which contains strychnine.

In some parts of northern Asia, and also of Melanesia and Polynesia, arrow tips are thrust into putrefying corpses. Other Melanesian tribes plunge their arrows and spears into the mud of miasmatic swamps, and thus coat them with bacterial cultures. This mud contains two pathogenic microbes, the vibrio of putrefaction and the bacillus of tetanus. The former is quickly killed by exposure to the sun, but the latter may remain active for months and perhaps for years. Old arrows produce tetanus in animals experimentally wounded with them, but new arrows cause death by septicaemia in 12 to 15 hours.

Strophantus hispidus.

Acocanthera schimperi.

Strychnos toxifera.

Euphorbia cereiformis.

The natives of the extreme north of America, who have the same origin and customs as those of northern Asia, also use the same arrow poisons, especially the juice of the *Anemone*.

The Indian tribes of the southern United States, Mexico and Central America poison their arrows with products of putrefaction and animal venoms, together or separately.

South America is the land where poisoned arrows are most used. The poison, known as curare, is obtained from a species of *Strychnos*, and it produces paralysis without causing death. The vine, which is filled with a very acrid milky juice, is cut into small pieces which are crushed and macerated in water for 48 hours. The liquid is pressed out, filtered and slowly evaporated to a suitable consistence. It is then poured into small earthen vessels, which are placed on hot cinders, and the evaporation is continued with still greater care until the extract is quite dry, a little snake venom being added during the process. The solid extract is said to retain its properties indefinitely, if it is not exposed to the air. Nowadays, however, curare is employed almost exclusively for poisoning the darts discharged by blow-guns in hunting birds and small animals.

*Translated from Henri Coupin's article in *La Nature*.

Peat Industry in Italy

Quite a number of peat bogs are being worked at the present time in Italy in order to secure a supply of fuel. Much of this peat is too low a grade to compete with foreign imported coal, which accounts for the poor success of some previous enterprises of the kind, even when the object was reclaiming land. More recently attention was called to the nitrogen of the peat, but it is difficult to utilize this because the inert nitrogen must be transformed to an ammoniacal salt of a more active nature. The idea of using peat to produce water gas appears to be due to Dr. Mond, and the first plant of the kind to be erected in Italy was installed at Orentano. The important Osnabruck plant in Hanover was next in order, laid out by Drs. Frank and Care, but on account of the difficulties experienced in preparing and drying the peat, these works may be considered as yet in the experimental stage. The same holds for several English plants. The most recent work of this class has been carried out in Italy at Codigoro, and it is claimed that all the difficulties have been overcome. Here the peat, after drying and crushing, is taken to a furnace of the producer type some 30 feet high, in which the peat is fed at the top. The peat burns only at the bottom of the producer and the combustion is regulated by the use of a hot air and steam jet, and the steam is decomposed upon contact with the incandescent mass, thus producing a number of gases and among them water gas which rise to the top of the producer. This gas should be produced at the lowest possible temperature, and the nitrogen of the peat combines with the hydrogen in order to form ammonia. The gas thus produced is put through a scrubber to rid it of the particles of tar which it draws over, and from here it passes into a lead chamber where it comes in contact with a fine shower of sulphuric acid, which converts the ammoniacal gas into sulphate of ammonia, while the rest of the gas is purified, cooled, and then can be used as combustible under steam boilers, in drying ovens or can even be used as gas for internal combustion engines. By this process, three quarters of the nitrogen contained in the peat are transformed to sulphate of ammonia, and a grade of peat containing 2.5 per cent nitrogen will give some 170 pounds of this product per ton. In the first stage, the peat was dried in the furnace itself, but as this did not give good results, the drying was done outside. Fresh peat with 50 per cent water is dried so as to contain but 25 per cent. At present the plant works on a daily run of 1,500 cubic feet of peat, and this gives 50 tons sulphate of ammonia per month, but before long it is expected to double this output. The gas from the plant is used in an electric station of 800 horse-power output. These good results led the company to erect a second plant at Codigoro in 1912, and it now treats 17,000 tons of dried peat annually, with an output of 10 to 12 tons of ammonia sulphate per day. The peat bogs of this regions have 2,500 acres surface. From the above it will be seen that this industry is a promising one.

An Apparent Correspondence Between the Chemistry of Ingeous Magmas and of Organic Metabolism*

By Henry S. Washington

In a recent paper[1] it was shown that potassium and magnesium on the one hand, and sodium and iron on the other, tend to vary together in igneous magmas and the minerals formed from them. That is, igneous rocks and minerals which are high in potassium contain (of the two) much magnesium and but little iron; while if the rock or mineral is dominantly sodic iron will be high and magnesium low, if these are present. This relation seems to be independent of the silicity (amount of silica) and but slightly modified by the amount of calcium.

The object of the present note is to call attention to what appears to be a congruous relation of these pairs of elements in the organic world—briefly stated, it would appear that, of the four, iron and sodium are necessary for animal metabolism (magnesium and potassium very much less so); while magnesium and potassium are essential to vegetable metabolism, the other pair being of minor importance.

This correspondence is indicated by the following considerations, all of which are well known to biologists, so that it is only in their collocation and the pointing out of an apparent congruity in the chemistry of the mineral with the animal and vegetable kingdoms that there is any novelty.

It is well known that the blood pigments of the higher animals, hemoglobin and its congeners and derivatives, are protein bodies which contain iron as an essential constituent, and it has been suggested[2] that this element acts as the oxygen carrier in the vital processes in which the blood plays the all-important part. In the blood plasma sodium is an important constituent, its amount being several times that of the potassium, though the latter element is, apparently, more important in the cells. The amount of magnesium in the plasma is also very small.

As stated by one authority[3] it would appear that "potassium compounds are replaced in the [animal] organism by sodium chloride," and that as a consequence "common salt is, not only a condiment, but a necessary addition to the food." The universal and necessary use of sodium chloride in food by man and many of the higher animals need only be mentioned.

In plants, on the other hand, the active metabolic agent which enables the organism to assimilate carbon from the CO_2 of the atmosphere is chlorophyll, and it is now well known through recent researches[4] that this is a protein compound which contains magnesium as an essential constituent. In this connection it is of especial interest to note that chlorophyll is very closely related chemically to hemoglobin, the formulae and apparently the constitution of the two being almost identical;[5] except that the animal metabolic agent is an iron compound and the vegetable agent is one of magnesium, and that the former contains slightly more oxygen than the latter. In this similarity we are reminded of the association and mutual isomorphous replaceability of iron and magnesium among minerals.

In plants again, in contradistinction to animals, of the two alkali metals, "potassium, unlike sodium, is essential to plant life."[6] Water culture experiments have abundantly proved that, of the cations potassium, magnesium, and calcium are necessary to plant life, though a small amount of iron is requisite to the formation of chlorophyll, in which connection the close similarity between this substance and hemoglobin becomes of special interest. Sodium is not necessary to most plant existence.

Although of subsidiary importance, the relative toxicity of the several cations to animal and vegetable life is of interest, as bearing in the same way as the facts set forth above. It must, of course, be understood that toxicity is largely a matter of concentration and that we have to deal, here very briefly and inadequately, with the *relative* toxicities of approximately similar concentrations of the several elements. It is also to be understood that we shall consider only the four cations (Fe, Na, Mg, K) which here concern us, and disregard others, as Ca, as well as the anions or acid radicals.

To the animal organism the magnesium salts appear to be mildly toxic, or at least are very readily eliminated when ingested into the system, which is only true of the iron salts when taken in much greater amounts. That potassium is largely replaced in the animal organism by sodium has already been noted, and experiments by Loeb[7] and others, which can be but barely alluded to here, show that to many animal organisms potassium is distinctly toxic, its ill effects being neutralized by immersion in solutions of sodium salts.

To the higher plants, at least, the iron salts, especially those of ferrous[8] iron, are distinctly toxic when present in the soil in much more than the small amounts needed for its (possibly catalytic) action in the formation of chlorophyll. Likewise sodium salts are, especially relatively to those of potassium, decidedly toxic

Arrow and spear heads.

1. African; 2. Oceanica; 3. South American; 4, 5 and 6. Poison pots of various tribes.

toward most vegetable life, though some plants, even of the highest genera, have become halophytic and have adapted themselves to soils and waters containing relatively large concentrations of sodium salts. Even in these, however, it would appear that potassium is the one of the alkali elements necessary to the plant's existence.

Briefly put, therefore, these relations of activity and toxicity of the two pairs of salts are antagonistic in the two kingdoms; that which is active in metabolism and chiefly necessary for life in the animal being relatively toxic in the vegetable, and *vice versa*.

Finally it may be pointed out that, according to Reichert,[9] hemoglobin is entirely absent from the lower orders of animals, such as the protozoa, porifera and coelenterata, is rare in the echinodermata, and that chlorophyll is present in some of these, as the protozoa. Thus it might almost be suggested that the nearer the animal organism approaches the vegetable the less the influence of iron and the greater that of magnesium in assimilative metabolism.

The facts thus very briefly and imperfectly set forth seem consistently and collectively to lead to the conclusion that, in general, of the four elements discussed, iron and sodium are, relatively to the other two, jointly necessary to animal metabolism and existence, while, *per contra*, magnesium and potassium replace them as essentials for plant life. Here we have, then, though opposed in the two types of organic metabolism, the same congruity between the two pairs of elements that has been shown to exist in minerals and igneous magmas. Whether this apparent state of affairs is merely coincidental and due to such external factors as conditions of environment, or whether it is based on some fundamental chemical characters or relations of the elements involved, can not be adequately discussed here.

Thus it might be argued in favor of the first supposition that the presence of abundant sodium in the blood plasma is due to the fact that this may represent the sea water in which the present day animal's ancestors once lived; that the presence of iron in the blood pigments may be ascribed to the existence of this element in two valencies, ferric and ferrous iron, and their ready transformation from one state of oxidation to the other;[10] that the presence of potassium rather than sodium in plants may reasonably be connected with the greater resistance to decomposition and greater insolubility of the potassium than the sodium minerals, and the consequent greater tendency of the former to accumulate in soils; and, lastly, that the fact that chlorophyll is a magnesium compound may be correlated with the ability of this element to act as it does in Grignard's reaction, as has been suggested by Willstätter.[11] The relatively greater toxicity of potassium over sodium, as in Loeb's experiments with Fundulus, may be ascribed to selective absorption or membrane permeability. The connection between these pairs of elements in magmas and minerals may be ascribed to differences in solubility.

Each one of these or other such explanations, taken individually and separately, may be rational and valid; but taken collectively, especially in view of the congruity of the four elements in the mineral and organic kingdoms, they make it appear possible and indeed reasonable to ascribe the correspondence to some fundamental chemical relation between the elements involved, of which such proximate causal nexuses as have been suggested are the consequences. No hypothesis can be offered as to what may be the nature of this relation; only the mere possibility of its existence, based on the correspondences set forth in this and the preceding paper, can be suggested.

A New Method of Measuring Refractive Index and Dispersion of Glass in Lenticular and Other Forms

The methods commonly used for accurately determining the refractive index of glass require the material to be in the form of a prism. When the glass is lenticular it is also possible to measure the focal length, the radii of curvature, and the axial thickness at the vortex, but with small lenses this method is not accurate beyond the third decimal place. A new method consists in immersing the glass in an aqueous solution of mercury potassium iodide, the refractive index of which is adjusted until it agrees with that of the test-piece, and then determining the refractive index of the liquid in a refractometer. The accuracy of this method is sufficient to give five significant figures. Light from a sodium flame illuminates a straight edge in a slit one millimeter wide, an image of this edge being projected through a telescope objective into the plane of a second straight edge which is placed in front of an observing telescope. The glass to be tested and the immersion fluid are contained in a small rectangular glass cell having a carefully planed base plate, two millimeters thick, made of extra dense flint glass for which $n_D = 1.74$, and closed above by an air-tight plate to prevent evaporation and the formation of striæ. The cell is adjusted on the prism of a refractometer in the usual manner so that the refractive index of the liquid may be rapidly determined. The cell is placed between the objective and the observing telescope and the latter is focused on the test-piece. If the refractive indices of the test-piece and the fluid differ, the image of the first straight edge will appear double, and on traversing the second straight edge slowly across the field of vision of the observing telescope the surface of the test-piece will gradually darken while the side facets and the rest of the cell will show up brightly. On continuing the movement of the straight edge, these facets will also begin to darken until the whole field is black. When the refractive indices of the liquid and the test-piece are identical, the movement of the straight edge will cause the whole field to darken simultaneously and uniformly.

It has not been found possible to determine the refractive indices of glass for lines other than the *D* (sodium) line with the same degree of accuracy, but good results may be obtained by using colored filters for lines *C* and *F*, and a mercury vapor lamp or a cadmium arc for measurements of partial dispersions.—*Note in J. Chem. Ind. from an article by R. W. Cheshire in Phil. Mag.*

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*Proceedings of the National Academy of Sciences.

[1] H. S. Washington, these *Proceedings*, *1*, 574 (1915).

[2] Cf. Reichert and Brown, "Carnegie Inst. Publ.," No. 116, 24 (1909).

[3] O. Hamarsten (Transl. by Mandel), "Textbook of Physiological Chemistry," p. 564 (1900).

[4] Cf. S. B. Schryver, *Science Progress*, *3*, 440 (1909).

[5] Reichert and Brown, op. cit., 1; Schryver, op. cit., 444.

[6] E. Strasburger et al. (transl. by Porter), "Text-book of Botany," 173 (1898).

[7] Cf. J. Loeb, these *Proceedings*, *1*, 473 (1915); *2*, 511 (1916).

[8] It is suggested that the lesser toxicity of the ferric salts may be ascribed to their ready hydrolysis and the consequent formation of very difficultly soluble basic compounds.

[9] Op. cit., 2.

[10] Copper, likewise with two valencies, exists in the blood of certain lower animals, as mollusca, limulus, helix and sepia.

[11] The dependence of plant life on magnesium and of animal life on iron, and the difference in their functions, is expressed by Willstätter as follows: "There are fundamentally two kinds of life, which develop alongside of each other; the anabolic life with magnesium and the katabolic life (of animals) with iron, that is a reducing and an oxidizing life." See *Liebig's Ann. Chem.*, *358*, 65 (1906).

Problems of Human Nutrition*

Discrepancies in Current Systems of Dietetics

By Axel Emil Gibson, M. D.

1.—RAGTIME IN DIET.

As a general principle in diet the statement may be made that any effort toward simplification in the preparation and mixture of food means a positive asset to the general health of the commonwealth. For it is the inconsiderate, haphazard mixture of incongruous foodstuffs that lies back of almost the entire range of gastric and intestinal disorders.

Hence, "mono-diet," notwithstanding its uncertainties as to governing qualifications in dietetic allowances for a single meal, which may mean a mere slice of bread, or bread and butter, or bread, butter and cheese with or without a baked or raw apple, etc., indicates a vast advance in the evolution of diet, as compared to such systems of "health diet" that allow at a single meal a mixture of meat, tomatoes, fruit, salad, cucumbers and chocolate; or cottage cheese, "combination salad," custards, bananas, junket and a glass of buttermilk.

In the harmonies of diet the system of "mono-diet" may be compared to a musical performance made up by a single solo instrument—some piccolo, drum or horn—which, though monotonous, and symphonically incomplete, is yet capable of producing rhythmic consonance and power; while the mixed system of diet corresponds to a grotesque *ensemble* of sounds and voices, in which every available complex sound-producing instrument, from a saxophone to a steam-organ, is engaged in the performance, grinding out a veritable dietetic ragtime, with a possibility of throwing every strain of digestive rhythm into gastric and intestinal discord.

Yet the purpose of diet should be neither a ragtime-medley nor a one-string-solo performance. The aim of eating should be no more an experimentation as to finding out the minimum on which an individual can subsist without incurring a risk of functional breakdown, than it should be to ascertain the maximum in which he can indulge without bringing about physiological explosion. Diet should have a higher purpose than merely to serve as a means of finding out the limits of bodily safety in the simplicity or complexity of a man's relation to his digestive capacities. The true diet should be to ascertain and sustain the true nutritional needs, conditional to an individual's highest moral, intellectual and physical development. And, if after a close and convincing analysis we should find a certain system of diet more effective than any other, in bringing out the best and strongest within us—physically, morally, intellectually—we should adopt this system, whether it be mono-diet or poly-diet.

Natural Disposition as a Guide for Diet.

In the complexity of modern industrial and sociological life any thumb-screw standardization of individual diet is unsafe and unreliable. Moral disposition, nervous intensity, rationality, preceding habits of life and diet, etc., must be accepted as indispensable factors, as necessary for a scientific determination of the specific needs in individual dietetics, as the appreciation of a person's anatomy in terms of appropriate measurements is necessary for the tailor to enable him to turn out a fitting suit of clothes.

And as digestion for its efficacy depends on the nervous disposition of the individual, so a fruit diet—which for the well-nourished, self-possessed, equipoised type of man would mean added health and power—for the neurasthenic, highstrung and eccentric, may prove disastrous. Milk may paint pink of health on the cheeks of one case and the shade of yellow jaundice on another. Sauerkraut, sour pickles, even vinegar and beer, may go well with a diet on salami, pork meat, Frankfurter sausage and Roquefort cheese; while for a person living on natural foods—grains, fruits and vegetables—such an indulgence must inevitably lead to digestive disaster. A poisoned system requires antidotal poisons for its neutralization; and physiological or digestive tolerance is entirely a matter of metabolic power of neutralization.

2.—RUDIMENTARY PRINCIPLES IN DIET.

The rudimentary principles of a hygienic diet are very few and very simple. They may be briefly summed up in the avoidance of certain physiologically intolerable combinations, such as acids with starches, milk with proteids, meat and carbohydrates—or, in other words, fruit with any form of food; meat with milk, fruit or cereals; free sugar in any man-made combination; acids with meals—and in general avoid any product not grown on a tree or attached to a root. "What God has united shall man not separate," is a principle applicable not only to matrimonial relations but to every relation in which man stands to creative life.

The above mixtures, whether applied to the lean or to the fleshy, to the neurasthenic or splenetic, to the sick or to the well, are antagonistic in their very nature, and tolerable only to the extent the indulging individual has reserve forces by which to subdue the inevitable fermentations. Immunity to poisonous mixtures is in appearance only. For while a person may possess sufficient nerve strength to defy the immediate effect of a poison, the indulgence is marked by deeper but masked changes, due to the losses sustained by the system in the neutralization and elimination of the offensive products. The gradual sinking of the vital column in the barometer of life, as registered by present vital statistics, shows unmistakably that the individual is indulging in dietetic errors that foreshorten his natural span of life.

3.—DIET AS A PERISTALTIC WHIP.

To most dietitians the main object is to prepare their food-mixtures with a view of moving the bowels of the patient. This, however, is a misconception of the real value of diet. As there are two ways of increasing the activity of your horse, so there are two ways of stimulating a sluggish bowel: by whipping or feeding. The one is irritation, the other nutrition. And to stimulate a system into a physiological heightening of its activities, without imparting a corresponding amount of nourishment, is no less ridiculous than the notion that a horse can be strengthened by a systematically applied whip.

Peristalsis is due to a wave of nervous energy arising in the semi-lunar ganglia and solar-plexus, whence its momentum is dispensed throughout the intestinal coil. The process resembles the mechanical movement of a watch, in which the wheels receive their impulse from the movement generated in the static, high-tensioned power of the coiled-up mainspring. And furthermore, just as in the case of a weakened mainspring, the watch may occasionally be made to show the correct time by an appropriate manipulation of its hands and wheels, so intestinal peristalsis may be temporarily regulated by mechanical or chemical irritation, without a single momentum of vital energy having been added to the nerve life of the organism.

4.—IRRITATION OR NUTRITION AS A REMEDY FOR CONSTIPATION.

Intestinal irritation leading to peristaltic activity may be due to two origins, mechanical and chemical: to the swallowing of coarse substances, such as bran, raw cornmeal and even sand, by which the sensitive nerve filaments of the intestinal membranes may be lashed into movements of segmental peristalsis, or to the fermentation of irreconcilable and hence poison-generating food mixtures, which by the efforts of nature to eliminate them from the system causes the movement of the bowel—by sheer accident. This fact explains why a change from abnormal to normal diet may often in weak subjects cause temporary constipation. For a system having depended on mechanical irritation and pathological chemistry for its peristalsis must naturally feel weak and inefficient from the neglect and subsequent inanimation of its true peristaltic centers, the central batteries of the sympathetic nervous system.

From this it becomes self-evident that the nutrition, rather than the irritation, of the peristaltic nerves should constitute the basic factor in curing constipation. For as has been shown, while the irritation through coarse substances may bring about the desired results, yet it must be remembered that the energy spent in the process is not due to a corresponding increase of nourishment, but must be tapped from vital reserves stored up in the system for the purpose of sustaining the individual with renewed vigor at a time when, in the course of cyclic decline, he loses the power to meet his routine vital expenditure. And it is right in this fact, the premature spending of our vital "old age" reserve fund, that we find an explanation of the statistically corroborated, but otherwise, in view of constantly improving sanitation, incredible condition of a gradual foreshortening of the old age perspective of human life.

5.—VITAL ASSETS AND LIABILITIES THROUGH DIET.

Any increase of physiological activity not compensated for by a corresponding increase of nutrition means physiological expenditure beyond the margin of systemic assets—a situation which, if continued, must lead to insolvency and vital bankruptcy. Hence it must appeal to us as one of the most important undertakings in our evolution to get into possession of a working principle of diet in which should be contained, in practical terms, the combinations of foodstuffs to which the system could and would respond without incurring unwarrantable loss to its vital economy.

The profoundly true is ever the profoundly simple. The facts of life are not half as complex as the theories of life. The problem of life has its triumphant solution in a return to natural, yet clean and dignified processes of living—simplicity in place of complexity.

The "Deadline" in Bread-making.

The first step in this direction should be a clear appreciation of what constitutes the safe and sane preparation of that primitive, time-honored foodstuff which the popular mind has credited with being "the staff of life." Now, the bread should be made up by no other ingredients than those present in the complete grain itself—unsifted, unbleached, unmixed, but ground sufficiently fine to avoid the irritation, soreness, and often abdominal cramps which may follow the passage of coarse, indigestible grain kernels, tearing up the delicate membranous lining of stomach and intestines. Furthermore, the baking of the bread should be thorough, and with the end in view of dextrinating its starch and destroying its yeast spores. The latter are harmless if the bread is in the hands of an intelligent and qualified bread-maker. The yeast plant is a vegetable, which, by inhaling oxygen and exhaling carbon dioxide, opens channels and passages in the sponge and thus enabling the heat of the baking to reach every particle of the mass. It is only at the exhaustion of the oxygen, when the yeast plant dies of starvation, that the danger comes in. For, as a means and method of self-preservation, the yeast plant, in its supreme moment, generates a progeny—an anaerobic bacteria—which becomes equipped with the power to break up the structure of the grain cell and from its central depositories extract oxygen. This means the destruction of the cell and the subsequent conversion of the sweet sponge into sour, which, however, the practical but unscrupulous baker tries to remedy by adding to it a mixture of sugar, alum, cream of tartar, shortenings, etc., which serve to mask the taste and deceive the palate of the consumer. The art of bread-making consists in knowing the time when to bake it, and in sufficient honesty to refrain from taking refuge in counterfeits.

6.—DIET FOR THE EFFICIENT OR THE VEGETATIVE LIFE.

Yet while a piece of good bread may be sufficient to sustain animal, routine existence, it is not sufficient to adequately sustain the high-tensioned cellular energies involved in the attainment of highest cultural efficiency. Hence the devotee of mono-diet would quite improve upon his system if he added some three or four black figs or prunes and a similar amount of walnuts to his breakfast of a piece of whole-wheat bread.

On the same basis of rigid dietetics, the mono-dietitian may find a meal of physiological sufficiency in a single dish of cottage cheese, yet if to the latter be added a teaspoon of ground Brazil nuts, a tablespoon of chopped green onions, lightly dusted with powdered chili-con-pine, as an aid to the digestion of the cold mass—while enjoyed with a slice of whole-wheat, well-toasted bread and unsalted butter—the effect of the meal on the system would be heightened both from the standpoint of taste, assimilation and nervous efficiency. And lastly, we will find that while an Irish potato has proven itself adequate to maintain human life in action during long periods of time, yet the fact remains that there would be added a new force of efficiency to a man's supper if his dietetic solo was relieved by a soft-poached egg, a boiled or steamed onion, parsley and an ounce of unsalted butter. If then, at the time of retiring, when the stomach has had time to get empty, a bunch of sweet grapes or a ripe, fresh apple was allowed to round up the dietetic programme of a day, the dietitian could congratulate himself to have achieved the three cardinal virtues of a rational diet: digestive facility, non-fermentative absorption and an

*From *The Medical Summary*.

s-power of efficiency. And without the attainment of these three objects diet remains a mere vegetative act, a haphazard feeding, gaged either by an overwrought asceticism of elimination or the insane promptings of an over-stimulated, unreliable, despotic appetite.

7.—THE VITAL BALANCE IN DIET.

Mono-diet, though readily losing itself in the extremes of eliminative prunings, has earned historic significance by introducing a buffer against the tendency of a great many of our health food reformers, whose entire "science" seems to consist in creating a variety of strange food mixtures—in their very nature unbalanced, intolerant and fermentative—and with no other basis of procedure than a vague sense of general gustatory fitness and semi-scientific theorizing as to the daily dietetic indulgence required for an individual to keep up a standardized, stereotyped scale of working calories.

In attempting to solve the problem of human nutrition, the fact must constantly be kept in mind that man is an individual, *per se*, and refuses constitutionally to be standardized or generalized into any fixed system of diet. His position as a thinking, feeling, willing entity makes his nature unique and boundless, involving energies not only due to physiological or laboratory chemistry, but to the spontaneous movement of his mind, the color of his motives, the heat of his emotions and the strength of his motives.

Homogeneity of Visible Radiations*

WHAT is known as homogeneous radiation, i. e., radiation of one specified wave-length, in X-ray work, corresponds to what is called monochromatic light in spectroscopic examination. The latter term—if not the former as well—is convenient, but purely ideal. For no matter how narrow the slit of the spectroscope, any spectrum line photographed will have a definite width and consist of an indefinite number of images of the slit, side by side, formed by rays of different wave-lengths. The observer sees a band rather than a line, shading off on both sides; the central, intense portion of the band will mark the natural vibration or "note" of the vibrating atom, the intensity becoming zero on both the sides, where the light is not sufficiently strong to affect the plate. The broadening of spectrum lines has been explained by Lord Rayleigh. When the discharge is sent through a gas and a condenser is inserted into the circuit, however, the broadening becomes anomalous, and that has not yet been explained. There are two effects. A strong magnetic field splits up a line of a spectrum into several components; that is the Zeeman effect, which has long been fairly well understood. J. Stark—and also A. Lo Surdo—quite recently observed, however, that strong electric fields of thousands of volts per centimeter also split up the lines in a different manner,[1] and an explanation for this Stark effect has not yet been found. It is with the condenser discharge and the Stark effect that Prof. J. W. Nicholson, D.Sc., of King's College, London, dealt in a discourse delivered to the Röntgen Society and published in the October issue of the journal of that society.

We have to go back to the general, or normal, broadening of any spectrum line and the natural "note" of the vibration. That note, Prof. Nicholson pointed out (following Lord Rayleigh), will be changed on the Doppler principle when the vibrating atom as a whole is moving, just as the note of the engine whistle appears to change when a train is rushing past an observer. When the electric discharge passes through a tube, bodily motions of diverse magnitudes will be going on in the vibrating atoms, and the frequency of the vibrations in the line of sight will be changed; these considerations have led to a knowledge of the relative masses of the atoms emitting the lines which would be monochromatic in the absence of bodily movements of the atoms. When, now, a condenser of variable capacity is introduced, the broadening is very much increased in an anomalous way, and the shading off is in some cases no longer symmetrical. When Stark succeeded in splitting up lines of hydrogen by electric fields—for instance, the Hγ line, which is itself separable into 27 lines, the distance between which increased as the electric field was made more intense—he suggested that this new (Stark) effect was at the root of the anomalous broadening of the lines under condenser discharge; his lines, he thought, would with a condenser discharge be sufficiently broad—perhaps by virtue of atomic velocity—to overlap and to form a wide band. Together with Dr. T. R. Merton, Prof. Nicholson has tested this suggestion in a novel and interesting manner.

Their apparatus comprises the ordinary spectroscopic equipment (a Hilger deviating spectroscope or a concave grating, 20,000 lines to the inch) and an accessory, a neutral-tint wedge of the kind used for recording the sensibility curves of photographic plates. Such a wedge, so cemented to a wedge of clear glass that the combination forms a plane-parallel plate, is mounted vertically immediately in front of the slit, which has a width of 0.025 millimeter. The absorption by the wedge is not selective, and the wedge is so arranged that the slit is parallel to the direction of maximum increase of wedge thickness. The lower part of any spectrum line then passes through the thin end of the wedge and is little weakened, while the upper part of a line is more attenuated and the length of a line therefore shortened; the upper end of a line will mark the point where the light is just sufficiently intense to affect the photographic plate. Hence the most intense wave-lengths will give the longest lines, the weak wave-lengths will give short lines. When a curve was traced through the top ends of the images, Dr. Nicholson explained, measurements could be made on the plate, and, the law of absorption being known, the law of the distribution of intensity across the band be calculated. As it was very difficult, however, to determine where a faint line ended, the photographs were not taken in the ordinary way, but through a process screen, ruled with two systems of lines at right angles to one another, 100 lines to the inch. The lines then appeared resolved into series of small dots, extremely close to one another, and instead of picking out the extreme boundary of visibility, the experimenter picked out the last black dot in any direction. In that way they had practically eliminated the personal equation in drawing the intensity curves, and the results thus obtained were much more concordant and in agreement with theory than those obtained by tracing the curve on ordinary photographs. Further particulars of the method were given by Drs. Nicholson and Merton in the *Transactions* of the Philosophical Society, June 28, 1916, page 547.

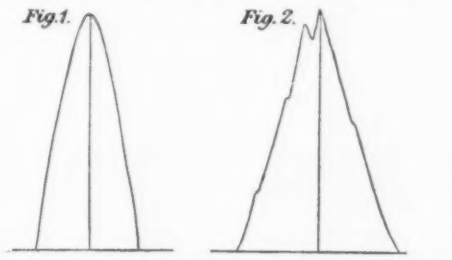


Fig. 1, annexed, illustrates one of the curves obtained, and it is nearly parabolic. If the lines were merely broadened by atomic velocities, after Rayleigh's theory, the curve would be a parabola of smooth, regular curvature. If, however, the law of intensity distribution was a simple exponential law, not in accordance with kinetic theory distribution of atomic velocities, every individual component should give a definite peak, and if the lines overlapped, as Stark assumed, a composite curve would result, showing more or less rounded peaks at spots where any component had maximum intensity. Fig. 2 illustrates such a curve of a helium line (already double in the ordinary discharge) obtained with a condenser discharge; that the number of kinks on the two sides was not the same was probably due to the fact that the line was not simple to start with. These photographs supported Stark's suggestion, quantitatively and qualitatively. The ratios of the horizontal distances between the kinks were really the ratios of the distances between Stark's components. Thus in a condensed discharge the splitting up of the lines was the same as that which occurred with a field of, say, 30,000 volts per centimeter—Stark has gone up to much higher volts—applied directly to the tube. Each of these lines was broad enough to overlap its neighbor, but this broadening was not of the same kind as the broadening with an ordinary discharge. The nature of the curves [it will be seen that the curvatures are of the opposite sense in Figs. 1 and 2] showed that the intensity distribution followed a simple exponential law and could not be explained on Doppler's principle by atomic velocities. There were thus two phenomena, different wave-lengths and a curious broadening, the Stark effect. The lines broadened more and more, quite apart from intensity, as they receded from the central line of the ordinary discharge. What the Stark effect meant in connection with radiation is not yet understood. Dr. Nicholson did not suggest any explanation. Stark assumed that the broadening was due to the electric field of neighboring particles. The atoms, Dr. Nicholson thought, might get closer together in their disturbance by the condensed discharge, even to the extent of interpenetration. An electron actually passing through an atom could easily produce, as calculation proved, a local voltage of the necessary magnitude. The atoms were, in fact, made to do the work themselves, instead of this work being applied outside the whole assemblage.

In any case the condensed discharge affords new means of studying the complex spectroscopic phenomena. Two years ago King and Koch described, in the *Astrophysical Journal*, another method of studying the structure of the spectrum lines. They caused the photographic plate to move slowly in front of the slit while continuously recording any change in the intensity of the radiation by the aid of a photo-electric cell. The method of Merton and Nicholson appears simpler, though it also requires that all parts of a slit remain uniformly illuminated. Spectroscopic phenomena seem to become more complicated the more they are studied; but these observations seem to show a way out of the difficulties. That applies also to homogeneous X-rays, a point to which Dr. G. W. C. Kaye drew attention during the discussion of Dr. Nicholson's discourse. When Barkla announced the discovery of characteristic homogeneous X-rays, each element seemed to have one characteristic wave-length; later on the K and the L series were distinguished. There may be 10 or more lines in each series, as the studies of crystals prove, and further series have been suggested. Nobody has probably yet experimented with really homogeneous radiations, and that fact might suffice to explain the different character of the Röntgen rays emitted by a bulb when excited under different current conditions. The homogeneity of emission depends very much on circumstances.

*Engineering.

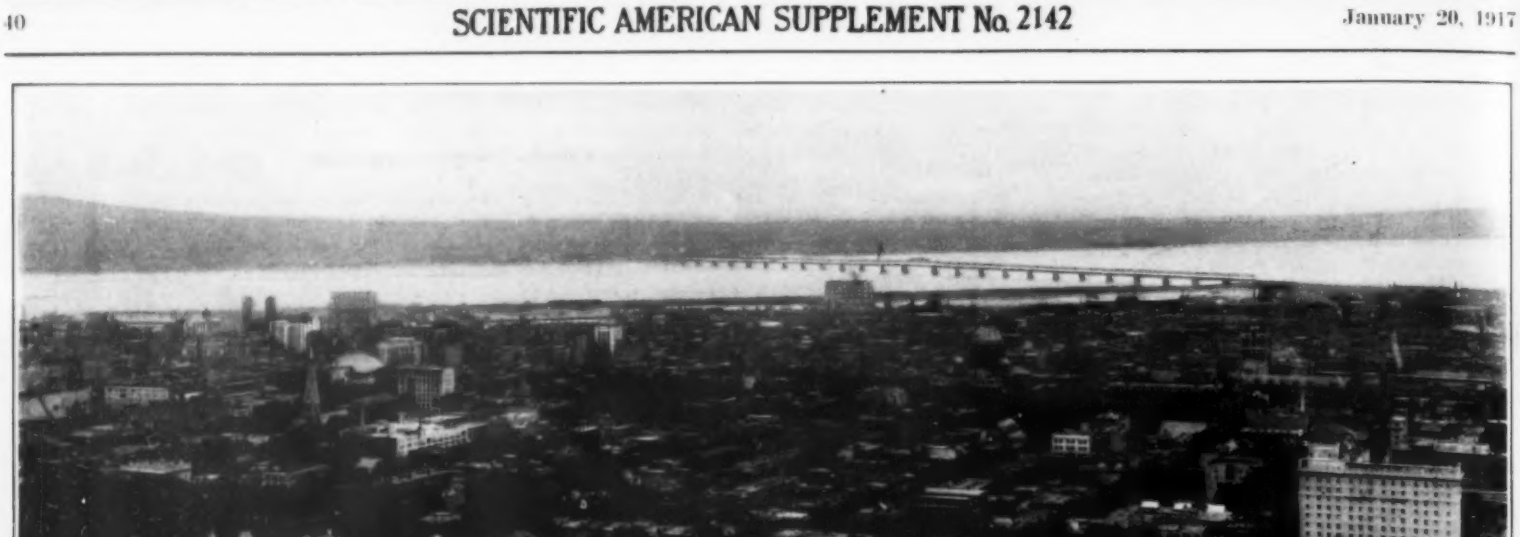
[1] Compare Sir J. J. Thomson's lecture, *Engineering*, vol. ci., page 380, April 21, 1916.

Train Ferries

THE use of train ferry boats has had the effect of considerably increasing the development of traffic on the Swedish State railroads and its connections with the neighboring countries, such as Denmark and Germany, especially between Trelleborg and Sassnitz in the island of Rugen. Within the last five years the traffic has increased to such an extent that the establishment of a special service of train ferries became indispensable. The principal idea of the two railroad lines was to assure a continuous running, and this has been so well carried out that there has not been the least interruption in the service between Trelleborg and Sassnitz since the start in 1909. As regards passenger traffic, figures show that such traffic is greatest in the winter season, showing that the passage in this season between Scandinavia and the continent of Europe is easier by the use of train ferries than by the combined use of railroad and boat, with the disagreeable transfers that must be made during the night, for these latter are quite suppressed by the new method. The question of freight traffic is still more important, and the adoption of the present method will be of great value for the relations with the continent, for the suppression of the transfer presents considerable advantages. For instance, between 1909 and 1913 the number of trips between Trelleborg and Sassnitz increased from 903 to 2,976 annually with 34,248 and 97,002 passengers respectively, while the freight traffic increased from 35,120 to 126,023 tons. At present there are in use four train ferry steamers, all of which are designed on the same plan by a Swedish engineer, W. Hök, and their gross tonnage is 3,074 tons, with 17 feet draft. The length measured on the railroad train deck is 371 feet; speed, 17.5 knots; total number of passengers, 1,800. The design of boats is such as to give the greatest safety, and they can navigate in very rough sea, especially on account of their great width. The vessel is built with double shell and divided into eight watertight compartments. There are four decks, including the train deck with double track of 302 feet long. The two engines are of the triple expansion type and drive two propellers.

Small Heaters for Use in the Trenches

NUMEROUS ready heating devices are coming out for soldiers' use, and one of the most practical consists in the use of a small cube of inflammable material which gives a good flame and will last quite a while. Along with a box of cubes is furnished a light iron support with a flat bottom. The vessel to be heated is put upon the support and one of the cubes thrown underneath so as to heat up. However, it is not absolutely necessary to use a special support, for any kind of a tripod can be employed, or even piled up brick or stone, and the cube is simply placed on the ground. One good idea is to fit a match into the cube so as to project out about half an inch or less, and now there is no need to hunt for a match box, but the cube is held in the hand so as to strike the match upon any surface, and after it is ignited it can be placed under the vessel. Such cubes are prepared so as to hold their shape until they are quite burned out.



The city of Montreal, as seen from Mount Royal.

Canada

A Summary of Its History and Economic Possibilities

Our neighbor to the north is a vigorous and alert young giant, fully alive to the possibilities of his vast estate. His foresight and initiative are evident in the way in which he is progressively solving the complex physical and psychological problems of his varied population. He has, too, reduced national advertising to a science; no one who saw the wonders of the Canadian pavilion at the Panama-Pacific Exposition would deny this, still less one who has carefully followed his wider methods of stimulating immigration and of superinducing in others the genuine enthusiasm which he himself feels for his boundless acres and their fertile soil.

The sweeping charter that in 1670 conveyed to a "company of adventurers of England" almost unlimited lordship over all the country watered by streams flowing into Hudson Bay was the opening chapter of a thrilling historical romance. The competition of the Northwest Fur Comany of Montreal inaugurated a bitter contest for supremacy that was marked by ruthless and bloody episodes ending only with the amalgamation of the two companies in 1821. Since 1859 this disputed district has been open to all, but the splendid orgnnization of the original company gave them a long lead over competitors.

In 1791 the governorship was superseded by an elective legislature. The establishment of free schools and other contributing causes led to disaffection between the French Roman Catholic and the British Protestant elements. Then the situation and the larger population of Lower Canada enabled this section to exercise a selfish control over Upper Canada that was naturally resented by the latter. This condition of affairs led to a proposal to combine all British North America into one legislative union. In 1854 a reciprocity treaty had been signed with the United States; since the Canada of that day did not include the maritime provinces, her sole access to the ocean being by way of the St. Lawrence River, this treaty gave a considerable impetus to trade with the United States, and the Canadian import and export traffic was largely carried by the canals and railroads of the United States, and afforded her seaports and transportation companies a large and steadily increasing revenue. Although the balance of trade was always in favor of the Republic, our statesmen saw fit to abrogate this treaty in 1866. The result was that measures were at once taken to increase transportation facilities and to open new markets for Canada. Within fifteen months of the repeal of the treaty, confederation was an accomplished fact, and construction work was commenced upon the Intercolonial Railway, which provided, at a cost of $20,000,000, an outlet for Canadian produce, with Halifax and St. John as terminal ports; the Bay of Fundy was linked to the St. Lawrence by the Bay Verte Canal, and existing canals were improved; commercial representatives were sent to South America and the West Indies with the purpose of building up a large direct trade; steamship lines were subsidized, and the shipbuilding and fishing industries were encouraged in every possible way. The Imperial Act of 1867 brought into close union the provinces of Upper and Lower Canada (Ontario and Quebec), Nova Scotia and New Brunswick; Prince Edward Island, Manitoba and the Northwest territories were added in 1870, and British Columbia in 1871. Thus it was that Canada, from the humble and somewhat precarious position of an inland colony, swung into line as the fifth maritime nation of the world; for a people of but four millions, this was indeed an achievement of which to be proud.

The Dominion of to-day has an area of 3,603,910 square miles, nearly equal to that of all Europe, while

Parliament building at Victoria.

its population of 8,075,000 (1914) but slightly exceeds that of the city of London. Of this population nearly 6,000,000 were native-born, some 800,000 were natives of the United Kingdom, 304,000 were from the United States, Austria-Hungary and Germany furnished 161,000, France 18,000, and most of the other nations of the world were represented; the Indians numbered 104,000, and there were about 3,500 Eskimo.

When the vast extent of the country is considered, extremes in temperature are not so great as might be expected from a comparison with European countries in the same latitude. The numerous lakes and rivers that constitute its unsurpassed water system materially modify climatic rigors. The winter temperatures are often very low, but the clear, dry air makes these periods quite bearable, and even enjoyable. The snow blanket is welcomed as not only protecting the late-sown grain and facilitating the collection of logs for spring transit, but also for the intense pleasure taken in swiftly traversing the white-piled roads in jingling open sleighs. The country east of the Rocky Mountains is of a level character, with some half million square miles of prairie and timber land perfectly suited to settlement, grain growing, and stock raising; the colder regions to the north are well forested, and could be made to yield barley and oats in considerable quantities; there are more than 900,000 square miles of this grass and timber country. West of the Rocky Mountains, British Columbia has close to 280,000 square miles of forest area, and there is a heavy belt of timber along the MacMillan River, in Yukon. The average lowest temperature for a series of years has been determined as 12 degrees below zero for Toronto, 17 below for Montreal, 23 below for Quebec and 38 below for Winnipeg; in the same years, the highest temperatures averaged 91 degrees for Toronto, 96 for Montreal, 90 for Quebec and 96 for Winnipeg. The rainfall in inches was: Toronto, 29; Montreal, 27; Quebec, 19, and Winnipeg, 17.

The Governor-General of Canada represents the executive authority vested in the Sovereign of Great Britain and Ireland, and is assisted in his duties by a Privy Council composed of fifteen heads of departments; there is a Parliament consisting of a Senate and a House of Commons. The Senate, limited to 104 members, at present has but 96; these are nominated for life by the Governor-General; of this membership, Ontario and Quebec each contribute 24, Nova Scotia and New Brunswick each 10, Manitoba, British Columbia, Alberta and Saskatchewan each contribute 6, while Prince Edward Island is allowed 4 members. Only those native or naturalized subjects of at least thirty years of age, residing in the province they are to represent, and holding in that province real or personal property to the value of $4,000, are eligible for nomination, and no senator may be a government contractor for any public works. Members of the House of Commons are elected by the people for a five-year term, or until the Parliament is dissolved; the province of Quebec is always represented by 65 members, and the number allowed other provinces is in proportion to their population; at present the House has 221 members.

Each of the nine provinces is self-governing, so far as its own business and revenues are concerned, with a lieutenant-governor and a separate parliament. The territories are each administered by a commissioner, assisted by a council of four members, all appointed by the Governor-General; except that Yukon Territory has a council of ten, elected by popular vote.

The Harbor of St. John's, Newfoundland.

Bow Valley, in the Canadian Rockies.

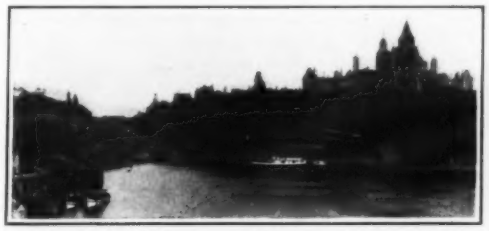
The public schools of Canada are free, and education is nominally compulsory; each province supports and controls its own system, assisted by government grants. There are nearly 26,000 of these schools, with an enrollment of one and a quarter millions, requiring an annual expenditure of $47,000,000; they are all unsectarian, except in Ontario, Quebec, Alberta and Saskatchewan, where separate schools for Roman Catholics are maintained. The Roman Catholics constitute nearly one third of the entire population of the Dominion. There are twenty universities, each province boasting one or more, with 500 instructors and 10,000 students. Five agricultural colleges offer thorough courses at very reasonable fees, and the Ontario Agricultural College at Guelph has students from no less than fifteen foreign nations, including Germany, Holland and Mexico. Numerous technical colleges and schools furnish instruction in the arts, law, medicine, applied science, civil, mechanical and electrical engineering, surveying, mining and metallurgy, chemistry, architecture and military science; twenty different institutions grant degrees.

The agricultural activities of the Dominion are extensive, varied and worthy of the closest attention. In 1911 there were 109,777,085 acres of occupied farm land, 48,375,000 acres of this being improved.

In addition to the general crops, mixed grains, husking corn, buckwheat and rye are grown on a large scale; the 1914 hay and clover amounted to more than ten million tons, and peas, turnips and potatoes were sources of large income. The area devoted to flax has decreased by more than two thirds in the past few years; the sixty flax mills once operated in Ontario are now reduced to thirty-four, only nine of which are running; this decline is due to various causes, chief among them being shortage of expert labor and lack of the best seeds for fiber. Some homespun is still made by the families of French-Canadian farmers; there are oil mills in Ontario and at Winnipeg that utilize the flaxseed in the manufacture of linseed oil; in British Columbia the crop is used only as fodder; formerly it was deemed an excellent crop for new ground, but oats have displaced it for this purpose. However, the future seems to hold some promise of better days. There are even now several improved processes by which it is claimed that short, poor quality fiber can be profitably used in coarse textiles.

The Dominion Government has done much to aid the farming industry. For twenty-five years it has had a Central Experimental Farm at Ottawa, and there are now seventeen other stations established throughout the provinces. To any of these the farmer may apply for any information he needs; each publishes, besides an annual report, frequent instructive bulletins. "Egg Circles," organized by the Department of Agriculture, provide means for the co-operative marketing of eggs at a fair profit. The eggs, stamped for identification, are handled by a branch manager; members are required to collect the eggs twice daily. The prices obtained for these choice, graded eggs average about twenty per cent higher than those paid by the local dealers. The huge grain elevators are also regulated by law with a view to aiding in every way the important industry of whose machinery they form so indispensable a part.

With the gradual reduction of the forest area, fur farming is becoming a large and profitable industry.



Parliament building at Ottawa, and the Ridean Canal.

The government of Ontario supplies fur farmers with small animals for breeding purposes. Fox breeding is carried on most successfully in Prince Edward Island where, in 1914, an official census showed 4,587 foxes in captivity; these animals and the ranches on which they were kept were valued at $20,000,000, and there are numerous other ranches throughout the Dominion. Other animals farmed are Karakul sheep (for the fur known commercially as Persian lamb and astrakan), skunk, beaver, muskrat, mink, marten and raccoon. Reindeer find their own food in the abundant moss of the country; they may eventually be used in place of dogs as draught animals; meanwhile they provide rich milk, good meat, and valuable hides. In Ontario, buffalo bulls are bred to Angus and Hereford cows; the hybrids are large, handsome animals, and the experiment is one to be followed with interest.

There are 500,000,000 acres of timber in Canada, about half this area being commercially valuable; one fifth of it is in Quebec, but British Columbia contains one half the stand. Douglas fir attains a good size, and ranks as the best wood for general building purposes; red cedar is ideal where exposure to the weather calls for a durable material; the mountain pine of the west admirably meets all conditions where white pine is usually specified, and the hemlock of that section, stronger than the eastern species, is used in framing, flooring and finish; the same requirements are met in Sitka spruce. There are thirty-one government reserves in western Canada, by far the largest area being in Alberta; a forest supervisor is placed in charge of each unit, and is held responsible for fire protection and improvement work. The interest and co-operation of the public are enlisted by means of museum exhibits so selected and arranged as to teach the broad principles of forestry and familiarize the people with the qualities and uses of their native woods.

The lumbering industry is regulated in part by the Dominion Government and in part by the provincial governments. Before timber may be cut on Dominion lands, a license must be obtained, the cost of the survey, the ground rent, stumpage dues and half the fire protection expense must be paid by the licensee, and all the timber he cuts must be manufactured in the country. Public auction is the method in general use for the disposal of such licenses. In 1914 there were cut in all Canada 3,946,254 M feet board measure with a value of $60,363,369, and this is exclusive of lath and shingles. The exportation of pulpwoods from Crown lands has been prohibited since January, 1900; the exports of pulpwood in 1914 were 972,508 cords, valued at $6,880,490, and in the same year 424,883 tons of pulp were exported, valued at $8,865,436; nearly 70 per cent of these shipments came to the United States. There are about seventy pulp mills in the Dominion, Quebec manufacturing 60 per cent of the entire output.

Canada has a coast line of some 12,780 miles, has inshore salt water areas of 1,500 square miles, and a fresh water area of 220,000 squre miles; her fisheries are the largest in the world, employing, with the salmon and lobster canneries, nearly a hundred thousand hands; the value of this produce runs well above $30,000,000 annually; about 2,000 vessels and 37,000 boats are used in the industry. There are 1,200 larger lakes, alive with fish of commercial value. Among the many varieties found are whitefish, trout, pike and pickerel. A promising industry is foreshadowed by the abundance of oil fish in the North Pacific, prominent among these being the rat fish, the dog fish, and the basking shark; the first named yields an excellent watch oil. The shell fish industry should also have a future; oysters, clams, cockles and mussels provide an almost inexhaustible source of sea food; the abalone of British

Harvesting grain in a wheat field of Western Canada.

Columbia is not only a delicacy, but its shell may be made into articles of jewelry and novelties, such as find a ready market in California.

The great mineral districts of Canada are Ontario, British Columbia, Nova Scotia, Quebec, Alberta and Yukon. The values of the metallic products of 1913 were: Silver, $19,040,924; gold, $16,598,923; nickel, $14,903,032; copper, $11,753,606; other metallic products brought the total value up to $66,361,351. The non-metallic yield included coal, $37,334,940; cement, $11,019,418; clay products, $9,504,314; stone, $5,504,639. Natural gas, asbestos, gypsum, petroleum, pyrites, salt, lime and other products bring the total to $79,273,461, and give the whole mining output a value of $145,634,812. The above items give some indication of the varied wealth of the soil. Among the rarer minerals found in the Dominion are antimony, used in high speed bearings, projectiles, etc.; barytes, used in paint; chromite, used in steel, fire brick and lamp electrodes; cobalt; feldspar, employed in pottery, and containing more than sixteen per cent of potash which might possibly be extracted for commercial purposes; fluorspar; graphite; molybdenum, a hardening agent for steel; palladium, employed in the manufacture of fine instruments; tungsten, and corundum. The Mines Department has recently tested radium-bearing ore from British Columbia, and the importance of the discovery is said to have been substantiated; the same province has large deposits of high-grade magnetite; only transportation facilities are needed to make its working a profitable undertaking.

Montreal is the largest producer of manufactured goods, with Toronto a good second. In 1910 the manufacturing capitalization of the Dominion was $1,247,583,000, with an output valued at $1,165,975,639 for the year.

The available water powers of Canada are placed by government report at no less than 17,000,000 horsepower, of which the province of Quebec has 5,000,000; of course, only a small part of this power is as yet utilized. In 1911 a report of the Commission of Conservation gave the total horse-power developed from this source as 1,016,521, of which 742,955 was used for electrical energy, and the remainder for other industries; the total power developed to-day is not far short of 1,800,000 horse-power.

The canal, river and lake navigation system stretches for 2,700 miles. The use of the boundary waters between Canada and the United States is regulated by a treaty signed in 1909 at Washington; this established an international joint commission of three representatives from each country, with jurisdiction, limited only by the terms of the treaty, over the use, obstruction, and diversion of these waters.

In 1913-14, nearly 1,500 miles of railway were constructed, bringing the total length up to 30,795 miles, of which 9,255 miles were in Ontario, 5,089 miles in Saskatchewan, 4,076 miles in Manitoba, and 4,043 miles in Quebec. At this time some 23,000 miles more were under construction. The Canadian Northern is a great transcontinental system with 10,000 miles of main lines and branches covering seven provinces; agricultural, mining and industrial interests are alike benefitted by its facilities. The 2,903 miles of the Canadian Pacific couples Montreal and Vancouver, and brings Montreal within eighteen days of Yokohama. The Grand Trunk Pacific, completed in 1914, runs from the Atlantic to the Pacific Coast and shortens the route between Europe and Asia.

Canadian commerce has a protective tariff, with preferential tariffs in favor of the United Kingdom and the colonies. Customs duties provided 57 per cent of the Dominion's revenue. Montreal took the lion's share of the total trade.

At the close of 1914 the registered shipping consisted of 4,718 sailing vessels and 4,054 steam vessels, of a total tonnage of 932,421.

For defense purposes, Canada is divided into six divisional areas and three military districts; active militia and reserve militia constitute the forces, which are under the command of the Governor-General, although nominally the command in chief is vested in the King. The men composing the active militia enlist voluntarily for three years; a small permanent staff is maintained, chiefly for the instruction of the volunteers.

Further Evidence as to the Relation Between Crown Gall and Cancer*

By Erwin F. Smith

1. *Fundamental concepts.*—It is my belief that a diligent study of tumors in plants will help to solve the cancer problem. Expressed in other words, my text is this: Cancer occurs in many kinds of plants in which it passes through an essentially parallel course of development to that of cancer in man and animals, some allowance, of course, being made for differences in the structure and development of plants. My concept is this, that fundamentally plants and animals are alike, that physical and chemical laws apply equally, that is uniformly, to all living things, and hence that discoveries relative to the fundamental cell-mechanics of animals apply equally to plants, and *vice versa*.[1] If cancer occurs in plants and is due to a parasite, as I maintain, then cancer in man must also be due to a parasite, and since I show that several kinds of plant cancers are due to the same organism, the differences being due solely to unlike tissue reactions, we may anticipate the same thing to be true in man, and search for one parasite rather than many.

2. *Human and animal tumors for which no cause has been discovered.*—These tumors fall readily into two groups which intergrade more or less. These are (*a*) encapsuled benign tumors, and (*b*) free-growing malignant tumors or cancers. I will here consider only the malignant tumors. There are several types of these; the simplest and the commonest being proliferations (1) of the connective tissues, resulting in fleshy tumors known as *sarcomas*, and (2) of the various kinds of epithelium, resulting in eroding tumors known as *carcinomas*. In addition to tumors of the brain and nervous system, which are sometimes malignant but which may here be left out of account, there are (3) very curious tumors containing mixed tissue elements of two germ layers (connective tissues, cartilage, striped and plain muscle-fibers, glandular tissue, etc.) some of which are benign while others are extremely malignant, and finally (4) embryonal teratomas which, in addition to the cancerous element, contain numerous foetal fragments, derived from all three of the primitive germ layers, often a great variety of tissue-fragments, variously fused and jumbled, but all embryonic and never coming to maturity.

The leading characteristics of these cancerous tumors are (1) Unlimited cell proliferation emancipated from bodily control; (2) Appearance of destructive secondary tumors, often in vital organs, which tumors are derived from the primary tumor either by development from dislodged creeping and floating tumor cells, or by uninterrupted growth from a chain of tumor cells originating in the primary tumor. These secondary tumors wherever they are developed repeat more or less closely the structure of the parent tumor. Add, to these manifestations, (3) a destructive action on surrounding tissues, which are crushed, absorbed or poisoned, and we have in brief the main phenomena of cancerous growth. The other phenomena are subsidiary and may be left out of account in this brief abstract.

3. *Earlier discoveries in plants.*—In 1907 the author and his colleagues (Townsend and Brown) proved that a common hyperplasia of various cultivated plants which had been for many years under observation in this country and in Europe and for which various causes had been inconclusively assigned (frosts, physiological disturbances, mites, myxomycetes, etc.) was really due to a polar flagellate schizomycete, named by us *Bacterium tumefaciens*. This was first cultivated from tumors on the Paris daisy in 1906, but afterward it was obtained from various other plants in several distinct strains (daisy strain, hop strain, etc.) and shown to be cross-inoculable on a variety of plants with resultant tumors in which no bacterial cavities or bacterial occupation of cells, vessels, or intercellular spaces could be seen in fresh material or demonstrated in serial sections by stains, and yet from which the causal organism was readily cultivable in small numbers by the common methods of the bacteriologist.

4. *Further discoveries.*—In 1911 I discovered in inoculated Paris daisies a parenchymatous tumor-strand connecting the primary stem tumors with deep-seated secondary tumors which had developed in the leaves some weeks after the stem inoculations. I also showed these secondary leaf-tumors to be possessed of stem structure, i. e., to have the structure of the primary tumor, thus following the law of cancer in man and animals. These discoveries were fully illustrated and described at that time in United States Department of Agriculture bulletins[2] and elsewhere. From the origin, structure and general appearance of these tumors I likened them to sarcomata.

5. *Other resemblances of crown gall to cancer in man and animals.*—Without entering into details which may be found elsewhere, a few other resemblances are here summarized: (1) No parasite visible; (2) Embryonic character and rapid multiplication of the proliferating cells; (3) Loss of polarity in the proliferating tissues; (4) Invasive surface growth of the tumor and absence of a capsule; (5) Non-granulomatous development of secondary tumors; (6) Growth in autonomous species from grafts; (7) Presence of degenerative changes in the proliferating cells as shown by behavior toward stains, by lobed and cleft nuclei, polynuclear cells, etc.; (8) Destruction of surrounding tissues; (9) Defective vascularization and early central necrosis with invasion of the open wounds by secondary parasites and by saprophytes; (10) Frequent return after excision; (11) Presence of atrophy and cachexia.

6. *Possibility of the existence of carcinomas and of mixed tumors in plants.*—Slides were shown suggesting that it is experimentally possible to induce the proliferation of glandular tissue and the epidermis (skin) of plants by bacterial inoculations, but so far no metastases have been obtained. This whole subject, however, is yet in its infancy and further reports will be made from time to time as results are obtained.

7. *Production of embryonal teratomata.*—Last winter I discovered that when growing plants are inoculated in the vicinity of dormant buds a new type of tumor is produced. This tumor bears on its surface diminutive abortive shoots (vegetative or floral), and in its interior, along with the cancer cells, numerous fragments of embryonic tissues, variously fused and oriented, often upside down and curiously jumbled. These tumors have never been seen by the writer in nature or at least if seen not recognized as crown gall tumors, but undoubtedly we shall now find them.[3] These tumors have all been produced with *Bacterium tumefaciens* plated from an ordinary sarcoma-like tumor of the hop received from the Pacific Coast eight years ago. The plants chiefly experimented on have been Pelargonium, Nicotiana, Lycopersicum, Citrus, and Ricinus. All of these and some others (Mangifera, Allamanda, etc.) have yielded teratoid tumors from inoculations in leaf axils.

The inoculated tobacco also developed secondary teratoid tumors at a distance from the primary tumor in both stems and leaves, i. e., tumors bearing numerous diminutive and abortive shoots, which at longest have lived but a few months. In other words, like the secondary tumors on the Paris daisy they have repeated the structure of the parent tumor but this time that which is repeated is not a simple sarcoma developed out of fundamental tissues but a complex tumor comparable to the embryonal teratomata or atypical teratoids occurring in man. Many attempts have been made in recent years to produce such tumors in animals but hitherto all experimenters have failed. Monsters, it is true, have been produced repeatedly by fragmenting eggs, and in other ways, but always they have been *typical teratoids*, never cancers.

However, the most striking result I have obtained is yet to be told. All the embryomas previously mentioned were obtained by making my bacterial inoculations in the vicinity of dormant buds (totipotent anlage) which were then apparently torn by the rapid growth of the tumor, the fragments being variously distributed in the tumor and there stimulated to develop, the result being embryonic growths of extremely variable size but all referable to the original disturbed shoot-anlage. If, however, inoculations are made in regions not known hitherto to contain totipotent cells, the same results can be obtained, e. g., I have obtained on the tobacco a shoot-bearing tumor from the middle of an internode, and numerous such tumors from various parts of leaves, twenty-seven on a single plant, seven on a single leaf, and too many it would seem to be explained on Cohnheim's theory,[4] i. e., as growths due to the development of embryonic "cell rests," which are conceived to be fragments displaced from the embryo in early stages of its growth and enclosed in other tissues where they remain dormant until a cancer stimulus sets them growing.

8. *Bearing of these discoveries on the cancer problem.*—It has been pointed out repeatedly that embryomas are the crux of the whole cancer problem. Hitherto they have remained unexplained. Now I have succeeded in bringing them into correlation with the simpler forms of cancer by showing that they also are specific tissue responses to the stimulus of a specific schizomycete. If one set of plant tissues is inoculated sarcoma develops; if another set, carcinoma (?); if a third set (and this time it must be a complex anlage containing totipotent or nearly totipotent cells), an embryoma develops. To a biologist, therefore, the conclusion is almost irresistible that human cancer must be due to a parasite, and that one parasite may well be the cause of the most diverse forms, as we have seen to be the case in plants.

*Proceedings of the National Academy of Sciences.

[1] See *J. Cancer Res.*, 1, No. 2, April, 1916, and *Science*, N. S., 43, 871, where I have elaborated this idea and also other ideas only touched upon here.

[2] *Bureau of Plant Industry, Bulletins* No. 213 and No. 255.

[3] As this goes to press I have had confirmation of this belief, having received from a florist in Massachusetts a crown gall of the rose showing abortive shoots growing out of stem tumor.

[4] For illustrations of teratomas produced in tobacco leaves by direct bacterial inoculation consult *J. Agric. Res.*, April 24th, 1916, Plate 23.

Spark Ignition*

The Effect of Spark Intensity on Ignition in Internal Combustion Engines

By J. D. Morgan, A.M.I.C.E., A.M.I.E.E.

THERE are current among engineers two opposed beliefs regarding the effects of spark intensity on ignition in internal combustion engines. According to the one, provided a spark is sufficiently strong to produce ignition, an increase of strength has no effect on either the rate of combustion or the maximum pressure attained; consequently such increase has no effect upon the power developed by the engine. According to the other the strength of the spark does have an effect upon the power, and it is therefore assumed that the spark strength influences both the rate of combustion and the maximum pressure attained. Obviously both assertions cannot be true, yet it is possible that the one which is untrue has some foundation in fact, and has evidently arisen out of a misinterpretation of experimental results.

Regarding the terms "strength" or "intensity" as applied to sparks for ignition purposes, no clear meaning is or can be attached to them. The terms are unsuitable because as ordinarily used they refer to the total heat energy of a spark, and this alone does not determine the ability of a spark to ignite a given gas mixture. To meet the difficulty the term "incendivity" has been proposed by the writer[1] to denote the property whereby a spark produces ignition of a combustible gas. The term is convenient for descriptive purposes, but no quantitative definition can yet be given. In the absence of a standard of incendivity sparks are ordinarily compared by measurements of their heat contents, except in special cases where they are referred to the energy supplied to the particular circuit which produces the sparks.

The principal investigations on the subject of spark ignition in internal combustion engines have hitherto been carried out by means of engine tests, the effects of different sparks being observed either on explosion diagrams or brake measurements. For the purpose of the investigation here recorded it was decided to explode in a chamber of constant volume weak quiescent gas mixtures at normal temperature and pressure, for the reason that the main facts can be more easily and definitely determined in this way than in engine tests, where the variable factors of the problem are less easily controlled. The sparking was in all cases at one position, this being approximately at the center of the explosion chamber.

In carrying out the experiments a mixture was found by trial which produced explosions of moderate rapidity, as the indicator diagrams of such explosions can be more easily and accurately compared than those obtained by very rapid or very slow explosions. Using throughout a coal gas mixture of the same composition, sparks from the following sources were employed:

(*a*) High tension magneto.

(*b*) Induction coil with cam operated make-and-break (primary supplied by 12-volt circuit).

(*c*) Induction coil with vibratory make-and-break (primary supplied by 4-volt circuit); 200 vibrations per second.

(*d*) Lodge condenser apparatus, vibratory make-and-break (primary supplied by 8-volt circuit); 70 vibrations per second.

The above are the principal types of apparatus used in practice. The heat contents of the sparks measured by means of the author's thermal balance were as follows:

(*a*) 0.01 joules per spark at 120 r.p.m.
0.03 joules per spark at 1,000 r.p.m.
(*b*) 0.02 joules per spark at 80 r.p.m.
0.0018 joules per spark at 1,000 r.p.m.
(*c*) 0.0005 joules per spark.
(*d*) 0.026 joules per spark.

In all cases the diagrams were identical, both as regards the rate of combustion and the maximum pressure. From this it is evident that provided a spark is capable of producing ignition, increase of incendivity has no effect upon the power developed in the engine. This result confirms what has previously been ascertained from engine tests. The fact has not yet, however, met with general acceptance among engineers.

Having regard to the foregoing, the question arises: What ground is there for the belief that engine power is affected by the incendivity or so-called strength of the igniting spark? The experience is common among users of internal combustion engines that an increased spark sometimes results in improved operation of an engine, particularly when weak explosive mixtures are employed. The answer is to be found in the fact that an explosive gas mixture requires for its ignition a spark having not less than a certain incendivity, and the latter varies with the nature and proportions of the mixture. When the proportions of the mixture are at or near the upper or lower limits beyond which ignition is impossible the required incendivity is high. But as the proportions approach that of maximum explosibility the required incendivity rapidly diminishes. Hence for a given gas mixture a certain minimum incendivity is necessary in the spark. If the incendivity is near the limit a diminution in the explosibility of the mixture may result in no ignition, or only intermittent ignition. This can be rectified by employing a spark of higher incendivity, providing a greater margin for gas variations. In a gasoline engine, particularly when running at slow speed, weak mixtures requiring strong sparks for their ignition are often obtained, and when the ignition system is insufficient to provide suitable sparks defective operation of the engine ensues. On replacing the ignition system by another producing stronger sparks the engine works satisfactorily. Arguing from this, the user concludes that the better spark has increased the power of his engine by increasing the rate of ignition or the maximum pressure, whereas actually it has only eliminated misfires.

From the practical standpoint the facts relating to "single point" spark ignition in internal combustion engines are comprised by the statements (1) that provided a given spark is sufficient to produce ignition any increase of incendivity does not affect the power obtainable from the explosion, and (2) that as the mixture passes from the proportion of maximum explosibility towards the higher and lower limits the required incendivity of the spark increases.

An outstanding and as yet unsolved problem in connection with ignition apparatus for internal combustion engines is that of defining the least spark required to produce ignition of a specified gas mixture, and with this problem is associated in general that of spark measurement. In the absence of an established theory of ignition any attempt to define a spark must necessarily be tentative, but some satisfactory temporary expedient is not impossible. Obviously the procedure of defining a spark in terms of the current in some part of the apparatus used for producing the spark is highly unsatisfactory, because sparks defined in this way are not comparable when produced by different apparatus. Any satisfactory method of spark measurement must involve nothing more than the spark. The most obvious and up to the present best developed method is the thermal one. In this it is usual to heat a quantity of gas by a succession of sparks until a steady state is reached, that is, the heat imparted to the gas is equal to the heat lost by the container. The average heating effect of the sparks can then be calculated and the heat content expressed in joules per spark. At first sight it would appear that the incendivity of a spark could be expressed as a function of the heat content, and if this were possible sparks could for practical purposes be defined in terms of joules per spark. There are, however, two facts which limit the usefulness of the thermal method. The first is that incendivity does not depend upon heat alone, but apparently on heat jointly with temperature, and the other that ignition seems to be the result of a cumulative action which can be set up by a succession of sparks when a single spark fails.

It is a matter of simple experimental proof that heat alone does not determine the incendivity of a spark. Using the same source of energy, say a magneto, two different types of sparks can be obtained, one by using the magneto normally and the other by connecting a condenser across the spark gap. The latter is contained in an explosion chamber which is filled with a weak gas mixture, and the magneto is adjusted so that working normally it produces a spark which will not ignite the gas. A condenser of suitable capacity is then attached across the gap, and by means of the resulting spark the gas may be exploded immediately. On measuring the thermal contents of the sparks it is found that the heat contained in the normal magneto spark is not less than that obtained with the condenser, and if a poor condenser is used it may be as much as 100 per cent more, as in one set of experiments carried out by the author. Yet the spark containing more heat failed to produce ignition where the other succeeded. The only apparent difference was the temperature. It might be suggested also that the duration was different, and the shorter duration of the condenser spark caused it to be accompanied by greater mechanical violence. But for this there is no experimental evidence. Both sparks are oscillatory, and the effective portion has apparently the same duration in both cases. It follows, therefore, that incendivity is not a function of heat only, but of heat and temperature. And as the heat-measuring instrument accounts only for total heat, the measurement of joules per spark is only useful for comparing sparks produced by practically similar apparatus.

The second fact, that ignition appears to be the result of a cumulative action, is of less practical importance in connection with ignition apparatus for internal combustion engines, seeing that single sparks are now more generally used. But for purely theoretical work the fact is of importance. Using a magneto provided with a variable resistance in its primary circuit to permit large variations of the spark in the secondary circuit, and employing a needle point spark gap, very small sparks can be obtained. Keeping the gas mixture constant and varying only the speed or the primary current of the machine, it was found possible to arrange a condition in which the gas would never ignite with the first spark, and only after a number of sparks had been passed through could ignition be produced. Owing to the extreme difficulty of insuring perfect uniformity of conditions (a trouble which is common in work of this kind), the results were not sufficiently regular to permit of a quantitative deduction, but the persistence of the phenomenon was such at all times that only one conclusion was possible, namely, that succeeding sparks produced a progressive change in the gas which finally resulted in ignition, in other words, the ignition was the result of a cumulative action. The pre-ignition period could be shortened by increasing the strength of the spark (viz., by increasing the speed or the primary current), or by adding a condenser across the spark gap. The largest pre-ignition period noticed was about 2 seconds with the magneto running at 5 r.p.m. In a previous investigation[2] using low tension sparks the author observed a similar effect. The results obtained with the less active sparks were more regular and the pre-ignition interval was longer. Having regard to the foregoing, the difficulty of defining the least igniting spark for a given gas is apparent, but, as previously stated, where under practical conditions only one spark (or a plurality of simultaneous sparks) is used for igniting an explosive charge the difficulty disappears.

The trend of scientific opinion concerning spark ignition is that the action is ionic. It is not suggested that the heat of the spark is unrelated to the process of ignition, but that the thermal and ionic conditions are intimately connected. A natural alternative, if not a substitute, for a thermal instrument for measuring incendivity is the electroscope. The application of the latter for this purpose is not easy, because a number of arbitrary conditions, such as the shape and position of the spark gap relatively to the charged surfaces, and also the magnitude of the charge itself, have apparently to be stipulated before measurements can be usefully compared. Nevertheless the electroscope appears to contain useful possibilities in this connection. It is a matter of simple experimental verification that the sparks of a condenser produce a larger discharge per spark than do sparks obtained when the condenser has been removed, although the heat content of the latter may be the same or even greater than that of the former.

*Engineering.

[1] "Notes on the Ignition of Explosive Gas Mixtures by Electric Sparks." Vol. 54, No. 254, *Journal of the Institution of Electrical Engineers.*

[2] "Notes on the Ignition of Explosive Gas Mixtures by Electric Sparks." Vol. 54, No. 254, *Journal of the Institution of Electrical Engineers.*

A Rotary Interrupter for Large Induction Coils

Complete Technical Description, with Instructions for Building

By Louis B. Laruncet

In the SCIENTIFIC AMERICAN SUPPLEMENT of December 25th, 1915, No. 2086, I described the construction of a high efficiency, ten-inch spark, induction coil of my own design, and stated the requirements for an interrupter in order to get the very best results with that or any other coil. But, as a reminder, the following description of what is required of an interrupter will prove useful to the reader.

An interrupter, as its name implies, has for mission to interrupt the direct current supplied to an induction coil, and transform it into a pulsating current, so that the repeated pulsations may create such variations in the magnetic field set up in the core of the coil as to generate a high voltage alternating current in the secondary windings. The work of the interrupter consists, then, in giving a period of contact, and a period of rupture of the current through the coil. The period of contact, i. e., the period during which current is flowing through the primary of the coil, must neither be too long, nor too short, there being a given duration to it for each type of coil, and each length of spark, and the break or rupture period must take place very abruptly. If the period of contact is too long, the current attains a maximum value, and keeps it for a length of time, before the contact is broken off, and not only does this create an abnormal amount of heat, and cause a loss of primary current, with no results in the secondary windings, but it also diminishes the sharpness of the break, and hence, the secondary spark is not what it should be, unless a monster condenser is shunted across the interrupter, and such a condenser is then a cause of loss of current in itself. If the period of contact is too short, then, the primary current cannot reach its maximum value, before being cut off, and although the break will be quite sharp, the resultant secondary voltage will be low and the spark will be reduced. In both cases, the power of the coil will be below its rating. From this, it becomes apparent that only the best type of interrupter should be used in all cases where good results are expected. I will, in this article, give complete building instructions for the construction of an interrupter of the rotary type which I designed and built, together with the coil already mentioned, and which has given me excellent service. This interrupter has been used for over one

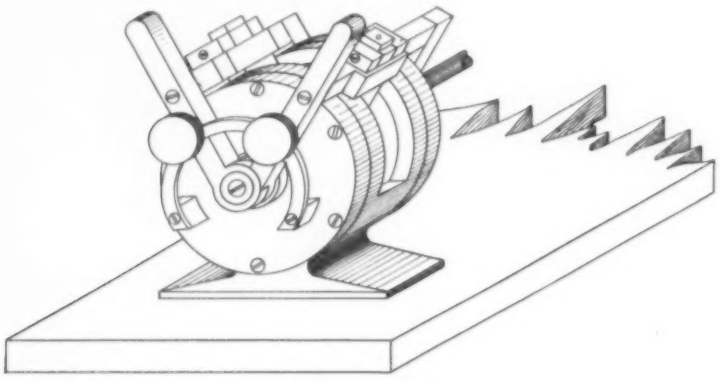
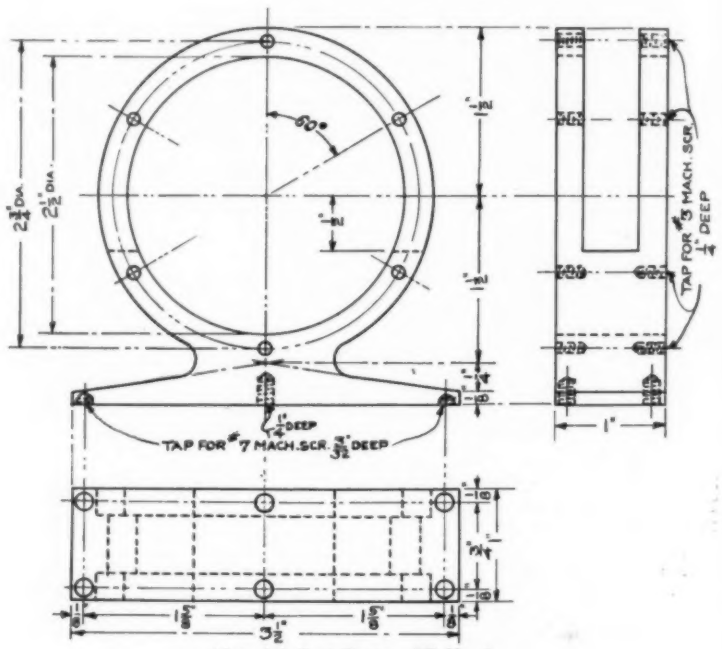
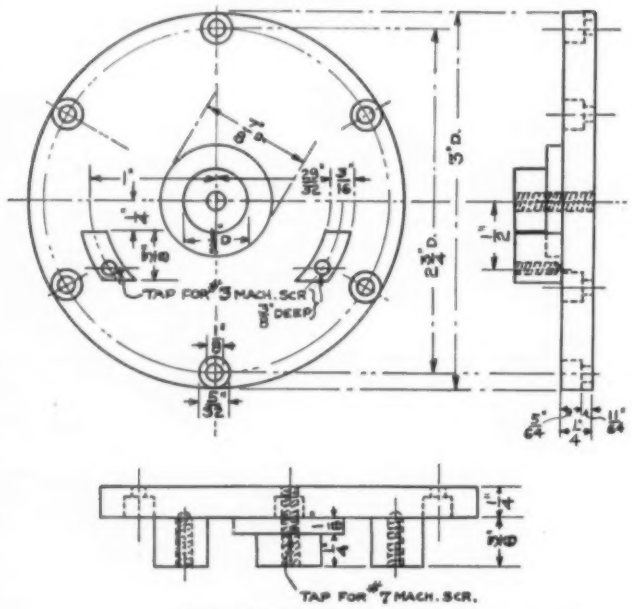


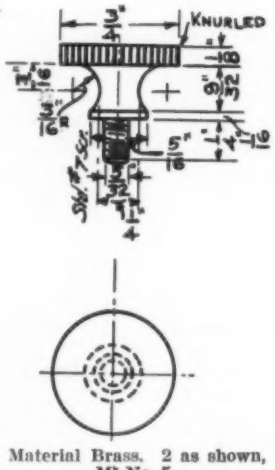
Fig. 1.—Assembly.



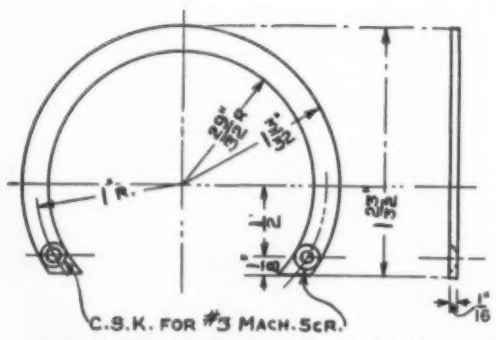
Material Cast Brass. Mˢ No. 1.
Fig. 2.—Main Frame.



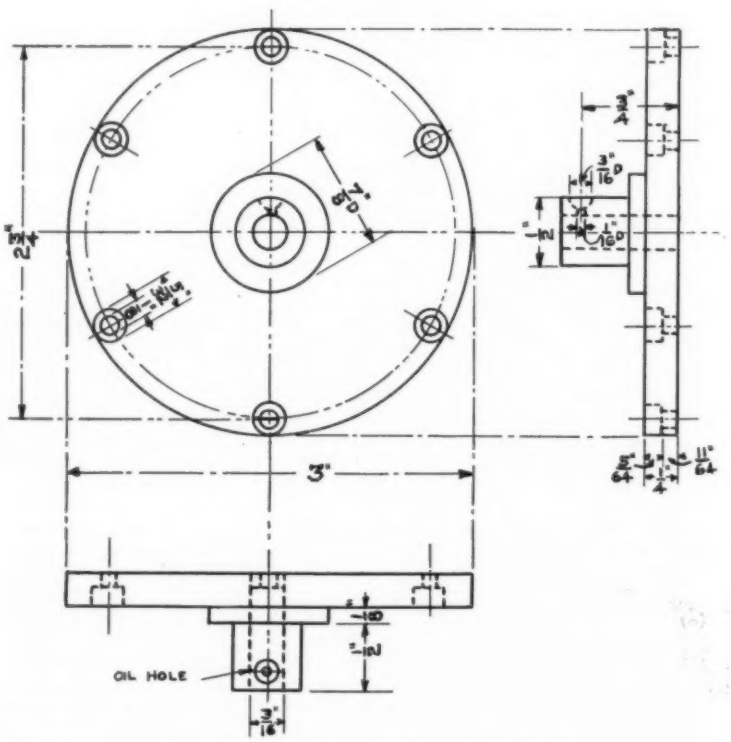
Material Cast Brass. Mˢ No. 2.
Fig. 3.—Front plate.



Material Brass. 2 as shown, Mˢ No. 5.
Fig. 6.—Clamp screw.



Material Sheet Brass. 1 as shown, Mˢ No. 4.
Fig. 5.—Clamping ring.



Material Cast Bronze. 1 as shown, Mˢ No. 3.
Fig. 4.—Back bearing.

year, working on an average five hours per day, which is what might be called a serious test for any apparatus of this type.

The rotary interrupter to be described provides three adjustments: Duration of contact, sharpness of break and duration of rupture.

Duration of contact and duration of break, together with an accurate timing of the spark—this last, although useless in most cases, finds, however, some uses that I shall not discuss here—are obtained by the setting of the two levers No. 7 and No. 8, which are in front of the machine.

The sharpness of break is regulated by the speed of the machine, together with the capacity of the condenser.

The interrupter shaft is coupled with that of a good electric motor able to run up to 5,000 R.P.M. or more, and controlled by a rheostat so that the speed can be reduced as low as 2,000 R.P.M.

A simple study of the machine will show that each adjustment is entirely independent from the others, and can be altered without any disturbance to the rest of the machine.

Sparking at the contactor, which is the only rotary part of the interrupter, must be avoided as much as possible, and particular care must be paid that the condenser used is large enough. Such a condenser has also the advantage of increasing the sharpness of break, and hence, producing a larger spark in the secondary circuit for a given amount of current than would be obtained otherwise, which condition is most desirable to obtain in any induction coil as it means a higher efficiency in operation.

For the construction of this interrupter, the following pieces will be required:

No. 1. One main frame (Fig. 2). No. 2. One front plate (Fig. 3). No. 3. One back bearing plate (Fig. 4). No. 4. One clamping ring (Fig. 5). No. 5. Two clamping screws (Fig. 6). No. 6. Two back parts for brush holder frame (Fig. 7). No. 7. One right operating lever (Fig. 8). No. 8. One left operating lever (Fig. 8). No. 9. Two brush holder frames (Fig. 9). No. 10. Four brush holders (Fig. 10). No. 11. Four brush holders (Fig. 11). No. 12. Two 5/16-inch x 5/16-inch x 3/4-inch long carbon brushes with six pigtails (Fig. 12.) No. 13. Two steel springs (Fig. 13). No. 14. Two caps for springs (Fig. 14). No. 15. One steel shaft 3 inches long (Fig. 15). No. 16. Two side plates for contactor (Fig. 16). No. 17. Two contactor segments (Fig. 17). No. 18. Two mica plates 3/8 inch x 3/4 inch x 1/16 inch thick. No. 19. One steel center screw, with perfect std. set screw sharp point. No. 7, 5/8 inch long all over, to go through front plate (No. 2) and to support shaft (No. 15) (Fig. 15). No. 20. Two brass keys 3/32 inch x 5/64 inch tapering to 1/16 inch x 5/64 inch, ¼ inch long, for keying shaft with side plates (No. 16). No. 21. Six flat head No. 7 machine screws 1/2 inch long with washers for fastening main frame to base. No. 22. Twelve fillister head No. 3 machine screws, 7/16 inch long all over, for fastening both front plate and rear bearing to main frame. No. 23. Two flat head No. 3 machine screws 3/8 inch long for fastening (No. 4) clamping ring to (No. 2) front plate. No. 24. Four fillister head No. 7 machine screws for fastening together brush holders (No. 6), (No. 7), (No. 8), (No. 9) and (No. 10). No. 25. Four 3/32-inch setscrews 5/16 inch long with sharp points for fastening caps (No. 14) in place. No. 26. Twelve flat head No. 3 machine screws 5/16 inch long all over for fastening contactor parts together. No. 27. One copper washer 1/2 inch x 7/32 inch thick to go over shaft. No. 28. Two pieces of rubber tubing 1/16 inch inside diameter 6 inches long, to slip over pigtails.

All the pieces marked "brass" on the drawings referred to can be made out of any material; iron or steel, for instance, if brass is deemed too expensive, and it is recommended that in every case, and no matter what the material used is, each piece be thoroughly nickel plated, or better still, if expense is not considered, that the whole machine be made of "white brass" or of "Monel metal," both having proved their high resistance to wear and corrosion, and giving beautiful castings that are very easily finished. Of course, even well japanned cast iron could be used, but it is not to be recommended. At any rate, No. 3 back bearing must be made of either bronze, Monel metal or white brass, and No. 17 contactor segments must be turned out of a copper rod, in order to secure smooth running in the bearing, and little or no sparking at the contactor.

All the above specified pieces having been obtained, and marked according to the drawings and bill of materials, the first step in the construction is the mounting of the contactor. Fig. 18 represents a section and an end view of the mounted contactor, and it seems that any one can mount it without any other explanation, except that the mica sheets must be glued to the copper segments by means of good thick shellac. Also, when keying the fiber end plates to the shaft, care must be taken to drive both keys home as nearly simultaneously as possible, and also to make sure that the contactor and shaft are at right angles and run perfectly true. It may be necessary to true the copper segments in a lathe, using a very fine pointed tool, and taking a very shallow cut.

The next step consists in fastening the front plate to the main frame as shown in Fig. 1, and then driving

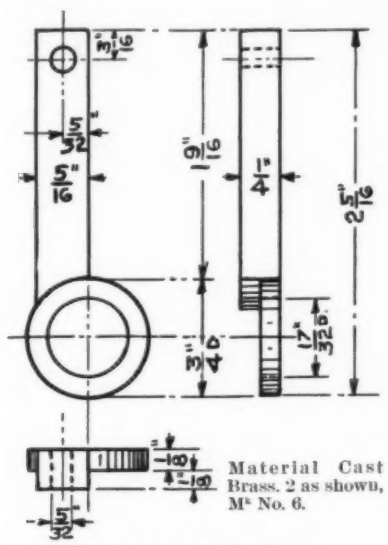


Fig. 7.—Brush holder frame.

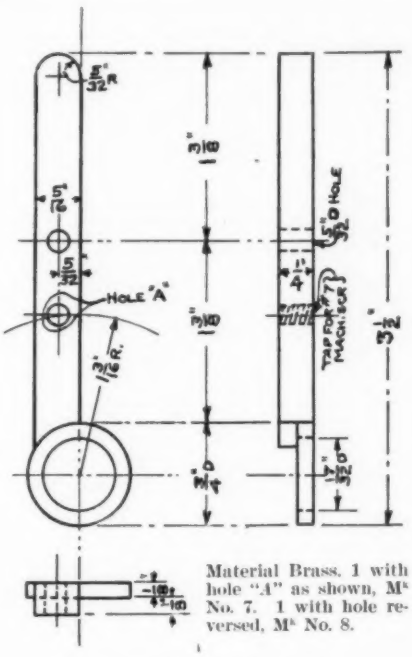


Fig. 8.—Brush holder frame.

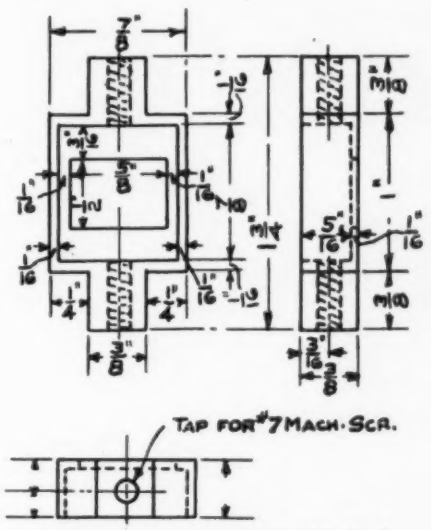


Fig. 9.—Brush holder frame.

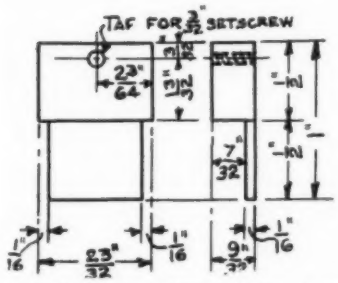


Fig. 10.—Brush holder.

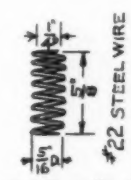


Fig. 13.—Brush spring.

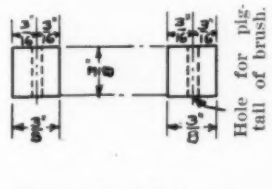


Fig. 14.—Brush cap.

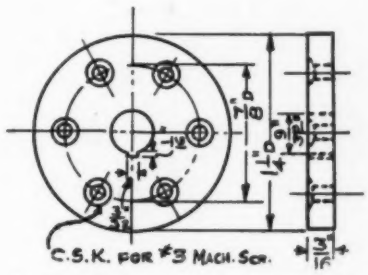


Fig. 16.—Contactor plates.

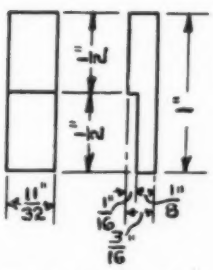


Fig. 11.—Brush holder.

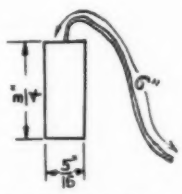


Fig. 12.—Brush and pigtail.

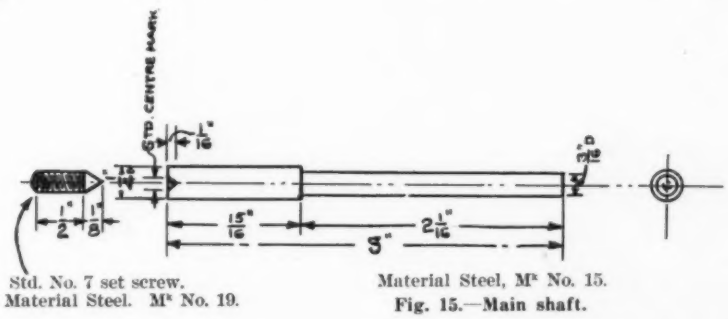


Fig. 15.—Main shaft.

screw No. 19 in the center of said front plate till its head is flush with the outside, after having first soaked the screw point in heavy grease.

Copper washer No. 27 is now slipped over the small end of the shaft, and the latter run through back bearing plate No. 3. This plate is in turn fastened to the main frame so that the oil hole points upward, and the center setscrew, No. 19, is adjusted so that the contactor can turn freely, but without any end play.

Brush holder pieces No. 10 and No. 11, two of each, are then set up inside their frame, No. 9, and their shape, together with reference to Fig. 1, are sufficient to guide the builder as to how to set them up. When the said brush holders are in place, the outlines of the tapped holes in No. 9 are marked on pieces No. 10, which are then removed, and in which holes 5/32 inch deep and conforming with the traced outline are drilled. These holes will allow screws No. 24 to hold the brush-holders solid in their frames. The holders No. 10 are now put back in place, and pieces No. 7 or No. 8, No. 6 and No. 9 are mounted together as shown in Fig. 1, the best practice being to mount together No. 6 and No. 9, then slipping No. 6 on their hub on No. 3 back bearing; then slip No. 7 and No. 8 over their hub on the front plate, and complete the mounting by driving and tightening the four No. 24 screws.

The clamping ring, No. 4, is then fastened to the front plate, and the clamping screws, No. 5, are placed in their respective holes in No. 7 and No. 8. The brushes are then slipped down in their respective holders, the pigtails threaded through the springs No. 13 and caps No. 14; the caps are forced down in their holders till setscrews No. 25 can be driven firmly into them. The top of the caps should then be a little more than ⅛ inch thick above the upper edge of No. 10 brush holder. The pigtails are run through rubber tubes No. 28 and then fastened to binding posts from which a lead will go to the coil and one side of the condenser, and another lead will go to the positive pole of the battery, and the other side of the condenser.

Nothing has been said so far regarding the coupling of the interrupter with its motor, for the size of the motor used, together with the disposition and form of its shaft, will suggest to the reader the best kind of coupling to use; the only point to be borne in mind is that the speed once adjusted must remain constant, and that it must have a range of at least 2,000 to 5,000 revolutions per minute. The motor developing about twenty watts.

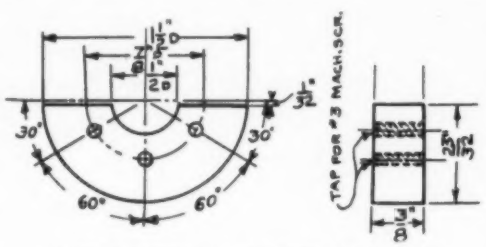
Before going any further and describing the proper operation of this interrupter, such as suggested by practice, a short description of the kind of condenser that should be used with said interrupter will prove helpful to the reader and will not be out of place.

It must be borne in mind that induction coils always need a very accurate adjustment if powerful effects are desired, and it is a proven fact that with an interrupter that, like the one described in this article, regulates the spark of a coil from one millimeter up to the full capacity of the coil, the intensity of the current varies with each length of spark although the voltage applied remains the same. From this it is evident that the condenser shunted across the interrupter must be made adjustable if high efficiency of the coil is desired, inasmuch as too small a condenser will not be able to absorb current fast enough to cause a sharp break, and too large a condenser will simply absorb current uselessly, a loss of power being the result in both cases; besides, a condenser is a heavy affair, and no one cares to have it any larger than necessary.

The condenser that the writer has found most satisfactory with the already described interrupter and coil is composed of six hundred sheets of 6-inch x 8-inch tinfoil separated from each other by 6½-inch x 7-inch pieces of good bond paper, the whole thing being thoroughly coated with shellac. The six hundred sheets are divided into twenty separate condensers formed of thirty active sheets, and connected with a twenty-point switch, enabling the operator to adjust his capacity step by step, until the ideal point is found. Such a condenser has a maximum capacity of four microfarads, and a minimum capacity of 0.2 microfarad.

Coil, interrupter, condenser, two switches and source of power (about six volts three amperes for the coil alone) being obtained, and mounted on their bases or frames, they are connected up together as shown in wiring diagram, Fig. 19, with No. 10 rubber and silk covered extra flexible cable.

When desired to operate, oil the interrupter, then start its motor by closing the small switch (*a*); then, by means of the rheostat, speed the interrupter up to about 4000 R.P.M. Then cut in all the condenser capacity, viz., four microfarads. Place the operating levers of the interrupter at an angle of about 60 degrees to each other, and clamp them by means of clamp screws



Material Copper. 2 as shown, M^s No. 17.

Fig. 17.—Contactor segment.

No. 5. Adjust the sparking points of the coil to the desired sparking distance, and throw the main switch (*b*) in. Sparks will begin to crash between the points, but the condenser and interrupter must be adjusted to produce the fattest spark without losses. Unclamp one of the levers, and move it slowly farther from the other one, thus increasing their angle until the spark either increases or diminishes. If the spark increases, go on till moving farther does not seem to increase it, and clamp the lever there. If the spark diminishes, bring the lever back to an angle smaller than 60 degrees until the fattest possible spark is obtained, and clamp the lever in place.

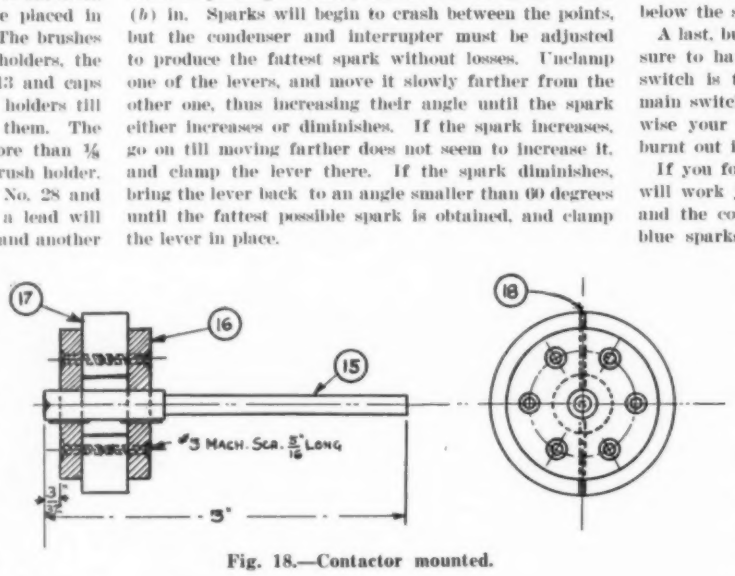


Fig. 18.—Contactor mounted.

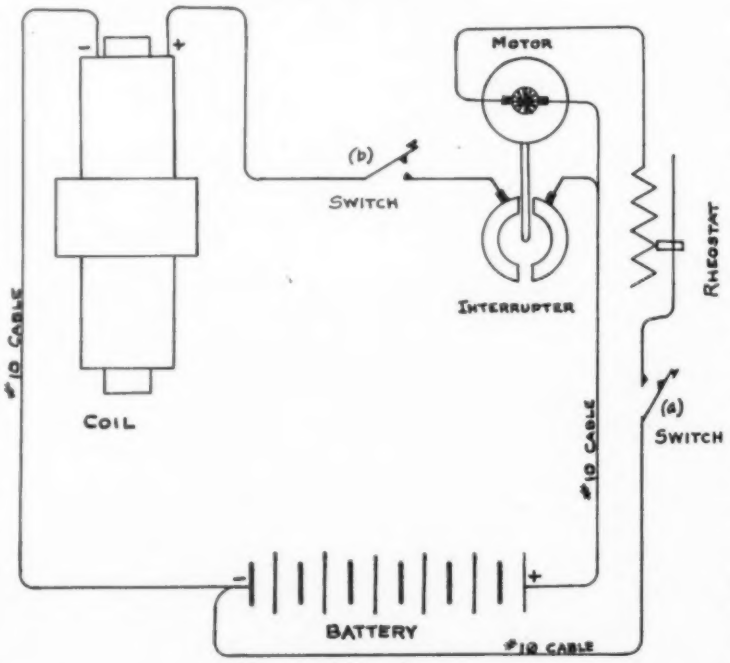


Fig. 19.—Wiring diagram.

Reduce now the condenser capacity until the next reduction seems to affect the quality of the spark. The outfit is then in tune for that special sparking distance, and should the length of spark be altered, the interrupter and condenser must be adjusted again. This is essential if best results are desired.

If very short sparks are desired, the motor must be run at its maximum speed, while if very large sparks are desired for a length of time, say over one hour of steady running, it will be found advantageous to slow it down to about 3000 R.P.M., and sometimes still slower. Of course, after each alteration in speed the duration of contact, and condenser must be again adjusted.

It is always a delicate proposition to adjust these different parts, but if it is borne in mind that under no condition should the coil require over seven volts or four amperes, the ideal adjustment can be brought out after but little experimenting.

It is a better practice, if the interrupter is to be used frequently, to order at least an extra set of brushes, for they are so easily obtained in the trade that it would not be advantageous to make them at home, and by having an extra set ready, the interrupter can be put into commission in a few minutes when the first set is worn out. It is impossible to give any idea of the life of a set of brushes; too many factors are to be taken under consideration, such as quality of carbon, conditions of manufacture, etc., and as a matter of fact, the writer has used some brushes over 1,000 hours without trouble, while some others crumbled to pieces after ten minutes of work. A good precaution is to remove the brushes from time to time, and keep their corners well rounded, so that they do not catch on the contactor, but rub smoothly over it. The contactor should also be taken out from time to time, any roughness smoothed out, and by means of a small three-cornered file, the mica plates kept about 1/32 inch below the surface of the copper segments.

A last, but important recommendation: Always make sure to have the interrupter running before the main switch is thrown in, and always throw off the same main switch before you stop the interrupter, for otherwise your coil would be in danger of being entirely burnt out in a very few minutes.

If you follow the above instructions, the whole outfit will work just as faithfully for you as it has for me, and the coil will keep on throwing off beautiful, fat, blue sparks, day in and day out, be it for wireless work, high frequency currents, or X-rays production.

The Clocks at the Greenwich Observatory

THE Sidereal Standard Clock constructed by Messrs. E. Dent & Co. is fixed to the north wall of the magnet-house basement, as in this apartment the temperature is kept nearly uniform. It has a detached escapement very closely analogous to the ordinary chronometer escapement, the pendulum receiving impulse only at each alternate vibration; consequently the escape wheel and seconds hand move only at alternate seconds (the even seconds). The pendulum is compensated in the following way: A central steel rod is encircled by a zinc tube, which rests on the rating nut on the steel rod; the zinc tube in its turn encircled by another steel tube, which rests at its upper end on the zinc tube, and carries at its lower end the cylindrical leaden pendulum bob attached at its center. Slots are cut in the outer steel tube, and holes made in the intermediate zinc tube, with the object of exposing equally all parts of the compound pendulum rod to the action of temperature. For final adjustment of the rate there is placed on the crutch rod a sliding weight which can be raised or lowered by a nut at the level of the crutch axis without disturbing the pendulum. The rate of the clock is so steady that when first mounted the barometric inequality was indicated with the greatest regularity, the daily losing rate of the clock being increased by 0.3 second for an increase of one inch of barometer reading. In the autumn of 1873 an apparatus for correction of this inequality was applied to the clock, and has been in action regularly since that time. The escapement of this clock is described with a diagram in Vol. III. of the *Transactions* of the Cambridge Philosophical Society. The Mean Solar Clock is also by Messrs. Dent, and has a zinc and steel pendulum. On the escape wheel arbor are two wheels, each containing thirty teeth, which close contact springs alternately, one wheel at the even, the other at the odd seconds. The currents thus set up actuate two relays by means of which various electro-magnetic clocks in different parts of the observatory are driven synchronously with the Mean Solar Clock. One of these is the old clock with the large dial in the boundary wall of the observatory.—*The English Mechanic.*

Refractory Materials—II*

Their Characteristics, Applications and Methods of Examination

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2141, Page 31, January 13, 1917

PROF. W. G. FEARNSIDES, speaking on "The Application of Petrographic Methods to the Study of Refractory Materials," gave scientific men and manufacturers a homely lecture and admonished them to pay more attention to the experienced foreman. Though there was a woeful lack of scientific data to help manufacturers beginning or starting on a new line, the foremen brickmakers and furnacemen who handled the materials, raw and manufactured, could impart a great deal of information, which needed to be collected and correlated. The scientific men should go through the works of manufacturers and users of the materials, listen to what experienced men said, spontaneously or under cross-examination, and translate that information into the international language of time and inversion-temperature, grain size and chemical composition which were the currency of the superior people who thought they knew. Makers and users should also work together as to the behavior of the products under unusual stress, etc., with a scientific man to hold the balance. In its best development the art of making refractory materials was in advance of science, but the practice of the art by unskilled makers left much to be desired. Fearnsides then passed to his own petrographic investigations, in which he had followed Sorby's method of studying the physical constitution of rocks and metals by rubbing down preparations to a condition of fair transparency, which meant to slices of a thickness of the order of 0.001 inch. To study the relation of "plums to porridge" in a brick and the character of the binder involved greater difficulties in the technique than the preparation of rock slides or of polished surfaces of metals. In bricks of basic materials (magnesia, bauxite, zirconia, chromite), however, which were characterized by a high refractive index, enough was known to foretell approximately how the bricks would behave in the furnace. With new-made silica bricks, and especially with firebricks, the determination of composition and of the intrinsic structure was far less easy, because with slices of normal thinness the new-formed minerals were such tiny crystals that they interfered with one another and appeared as a felted mass. Yet the characteristic inversions of quartz to tridymite and cristobalite in silica bricks were comparatively easy to observe, and one could thus judge of the heat treatment a brick had received. [Quartz, tridymite and cristobalite are modifications or polymers of SiO_2, differing in crystal form, density, optical properties and in stability at different temperatures, and quartz has been called a geological thermometer.] More satisfactory from the point of view of demonstration specimens were micro-preparations cut from the bricks from the linings of large furnaces when those furnaces were dismantled; the careful selection and study of the more successful of those highly-matamorphised products might suggest to scientific workers a probable direction for the manufacturers' further advance.

Dr. A. B. Searle said that he had for years relied more on physical and microscopical methods than on chemical analysis of materials for firebrick manufacture, for reasons which he had fully explained in his book on "Refractory Materials, their Manufacture and Use." This book had been announced for publication three months ago, but had to be reset owing to a fire at the printer's. The petrological method described by Prof. Fearnsides was by no means so new as might be supposed, though little had been published in this country; he had found it in extensive use in Germany in 1900, and had himself employed it since, especially the method of Wernicke, 1899, of ascertaining whether a silica rock would make good bricks; he examined the rock microscopically before and after treatment with stains. Co-ordination of research required some medium of communication accessible to all concerned; there was a trade paper which devoted special attention to the scientific and technological side of refractory materials, and if scientists would pay more regard to trade journals, much of the present overlapping and repetition of work would be avoided. Much of the apparent indifference among the manufacturers or refractories was due to two causes: Most of the firms were small and had not sufficient capital for research; and some of the more progressive firms had been unfortunate in the research work done for them by inexperienced students fresh from college. These considerations had induced him to start in practice as scientific adviser in 1901, and his clients felt fully justified in combining to maintain a central testing station and technological bureau dealing solely with clays, sands and their products. The method so successfully used in the development of the German refractory industries was to retain the ablest investigator by one firm or group of firms, so as to investigate all the problems arising, and not to be content with research carried out in State-aided colleges by men whose chief occupation should be educational. That method was free from the uncertainties of grants from the State, and the whole of the money was spent on the special problems for the benefit of those most entitled to it, while the universities were free to concentrate on questions of academic interest, for which they were expressly fitted. The analogous problems had been satisfactorily solved in the Portland cement industry by similar combinations of manufacturers, with complete success so far as they had gone; the Brown-Firth laboratory was another example taken from the steel industry. We cannot help remarking that Dr. Searle appears to advocate a peculiar co-ordination of pure and applied science, though we can feel with him to a certain extent; one might ask how his fossilized universities would train the scientific adviser.

Contenting himself, owing to the lateness of the hour, with a few remarks on "The Classification of Refractory Materials and Notes on Methods and Points for Investigation," Mr. E. P. Page said that this branch of science was still in its infancy, except as to materials like graphite and bauxite, and not ripe for classification. The customary distinction of acid, basic and neutral materials was arbitrary. The essential property was stability at all temperatures and conditions. Referring to different clays, substantially of the same percentage composition, Mr. Page showed that these materials might be as different as chalk and cheese and be classified in diverse ways.

Mr. Cosmos Johns, M.I.Mech.E., F.G.S., contributed a paper on "Silica as a Refractory Material," dealing in particular with the application of this material for acid and basic open-hearth processes. The silica was used, Mr. Johns stated, as sand to form and to repair the hearths of acid furnaces, and as silica brick also in the basic process. Silica bricks had been made for more than a century, and the art was still in advance of the science. Among recent researches a paper by Fenner on the "Stability Relations of Silica Minerals" deserved attention, as it explained some of the anomalies noticed by Day and Shepherd (*American Journal of Science*). Fenner noticed that the melting of cristobalite (about 1,625 deg. Cent.) really meant deorientation of crystalline structure, and it was fortunate that silica had a melting-range, instead of a melting-point. The temperature of the walls of an open-hearth furnace was very difficult to determine; with an optical pyrometer Mr. Johns had found $1,650 \pm 50$ degrees, while the flame temperature was about 1,800 degrees, the flame appearing bright on the background of the walls. The bricks carried the greatest load; but there was a greater margin of safety than might be thought, as only the face was exposed to this temperature. Examination of fractured surfaces of bricks which had done long service in furnaces showed the portion next to the interior of the furnace to be much darker and denser than the other parts; that "seasoned" portion was more refractory and stood temperature changes better than the original brick, and contained up to 15 per cent by weight of magnetic iron oxide (the most stable oxide); this oxide was not in combination or in solid solution, as it could be picked out by the magnet. That so much iron oxide should improve the brick was noteworthy; the fact might merely indicate long "annealing," but the magnetite might not be a passive constituent.

Ferruginous quartzes were not sought for as raw material for bricks; yet a Japanese quartzite with 4.5 per cent of iron oxide[2] had unexpectedly given a highly refractory brick, in spite of its dark color, and it would be interesting to try the addition of magnetic iron oxide to bricks; in the mixture the oxide would not be disseminated through the material as in the quartz, but it would approximate to the seasoned bricks. Bricks containing iron oxide should be burnt in an oxidizing atmosphere, to avoid the formation of possible ferrous silicates. This formation took place in the uptakes from the furnaces, and the bricks were corroded there by the reversals of the atmosphere.

Silica bricks were made by mixing crushed quartzite with a little lime and moulding and burning the mixture. The resulting complex mineral should stand temperature changes without cracking, be refractory at the highest furnace temperatures, resist reactions, and have a regular and small expansion coefficient. Differences in the size of the quartz fragments and in the nature of the heat treatment were perhaps more important than variations in the composition. The lime silicate, less refractory than cristobalite, was a necessary evil; the lime was required to bind the quartzite fragments, and the problem was one of grain size and packing. As the surface varied inversely with the size, large grains were desirable; but grains of uniform size gave a maximum of void spaces, hence there should be more than one size of grain. A continental firm made a very good brick from two sizes (7 and 3 millimeters), with the fine material resulting from the crushing as third size; other makers used similar sizes, but there were departures from this practice calling for experimental research. Fenner's inversion temperatures: A quartz → B, 575 degrees; B quartz → tridymite, 870 degrees; tridymite → cristobalite, 1,470 deg. Cent., concerned fine material, and a flux had sometimes to be used; but the relations were by no means simple, and unstable phases appeared in certain melts. The raw materials of refractories were not pure, and purity was hardly desirable. The occurrence of definite phases could not be predicted therefore, and the petrological examination of the cold brick (after burning or use) could not throw much light on the constitution. Quenching fragments from furnace temperatures might yield information. After determining the correct texture, time-temperature curves could be correlated to the behavior in service conditions, and in the effects of reducing and oxidizing atmospheres, the permissible range of temperature, and the use of catalysts and of various bonds might be investigated. As regards sands, Mr. Johns remarked that sand was used as received, except for drying. The grain should not be too small; the sand should be refractory, in a sense, yet it should frit when thrown into the hot furnace, without becoming viscous. Extreme purity of sand was no advantage when used in itself; the permissible range of impurity could be only tentatively suggested: Al_2O_3 up to 2 per cent or more; Fe_2O_3 up to 5; CaO or MgO, 0.5; Na_2O or K_2O, 0.15 per cent, provided only one of these constituents were present. But sands of lower standards might possibly be used, and were used.

Several representatives of the Geological Survey of Great Britain and of the Imperial Institute presented communications on the sources of refractory materials in this country; the exhibits, both from the Geological Museum in Jermyn Street and the Imperial Institute, were examined with great interest. Mr. J. Allen Howe first made a statement on 'The Recent Work of the Geological Survey on Refractory Materials." When the war broke out, he said, merchants, manufacturers and the Government had inquired about the mineral resources, and with the aid of what was left of his staff, the director of the survey, Dr. A. Strahan, had already produced five special reports on the mineral resources of Great Britain; a sixth, on refractory materials, was to follow. A good deal of information on the latter subject was scattered through memoirs; the museum also possessed the only long series of clay test pieces ever made in this country, by the late George Maw; that collection had often proved of value to engineers, and if only some organization of manufacturers and trained experimentalists had followed up Maw's work, there would have been no need of a meeting like this to-day. In order to collect samples and information as to locality, geology and extent of deposits, the country had been blocked out into field areas, field staff units had been at work since last Summer, and much material had already come in. Mines and quarries were visited and the producers of

*Engineering.

[2] According to a communication to Mr. Johns, by Captain Noda, Japanese Navy.

the raw stuff and materials were consulted. The principal users were likewise approached, and the first conference of this kind, arranged by Sir R. Hadfield, had been followed by a large number of conferences at other steel, iron, copper and smelting works.

They had not paid special attention to coke ovens, as the Refractory Committee of the Gas Engineers were looking after them [compare Dr. Colman's paper mentioned above] but they were in consultation with that committee. Some 1,500 samples, exclusive of typical bricks, had been received so far; though several isolated areas were still to be dealt with, the first stage of their task, the collection of raw materials and information, was nearly completed. The second stage, the chemical, petrological and textural examination, would take time, but they hoped soon to bring out a first portion, dealing with ganisters and silica rocks, a second portion on fireclays, and so on. Information as to refractoriness and other properties and tests was also to be incorporated in the report, though the methods adopted in preparing blending and firing could not be included. There would be, for the first time in this country, however, a publication dealing with all its refractory materials, and the records were to be continued.

Dr. Aubrey Strahan, F.R.S., director of the Geological Survey, was able to add some very encouraging remarks. The resources of Great Britain in materials, so far largely imported, were practically inexhaustible. Great Britain probably contained a wider and more varied assemblage of minerals than any other area of equal size in the world. Mr. Howe had pointed out that the Geological Survey was the only permanent organized staff of the country for the investigation of rocks and minerals in the field. The basis of the survey work was the construction of a primary 6-inch geological map of the whole country. The surveyors also noted down strata and outcrops which appeared of no value at the time; but the outcrops of certain sandstone beds in the coal measures and millstone grit of Yorkshire and South Wales, in which the well-known silica rock occurred, marked on old maps, had now proved of great service in this special task. The geologist had mainly to determine the reserves and characters of the raw materials. The manufacturer would be informed of the localities and properties of the rocks, specimens of the rocks themselves would be added to the collections of the Museum in Jermyn Street, where further information could be obtained. There had been a keen demand for the early volumes of their special reports, and the members of their staff had everywhere met with so cordial a reception that the report should be useful to the development of the industry.

Mr. T. Crook, of the Imperial Institute, referred to the work of this Institute, which, he said, had for many years been engaged in investigating the mineral resources of the Empire by means of mineral surveys and of laboratory research. The Empire was in quite a strong position as to refractory materials. Ceylon was a valuable source of graphite of exceptional quality, both in texture (flaky and fibrous) and composition; Canada also had considerable reserves; the flaky variety was found abundantly in a disseminated condition among the old rocks of East Africa and Nyassaland; a lower grade of amorphous graphite occurred in Natal. Chromite, chiefly valued as chromium ore, came from Rhodesia and from Beluchistan and Mysore, also from Quebec and Newfoundland. Bauxite was supplied by Antrim; the large reserves of Jubbulpore and Balaghat, in the Central Provinces of India, had hardly been attacked; very interesting also were the bauxite deposits of British Guiana, from Christiansburg and other places on the Demerara River, where a bauxite of 66 per cent of alumina could be mined; these deposits had attracted North American capitalists. Magnesite was well represented in the Empire's mineral resources; India had for several years mined considerable amounts in the chalk hill deposits of the Salem district (Southern India), and deposits were now worked in Travancore; there were also important deposits at Malelane (Transvaal), at Heathcote (Victoria, Australia), and in various parts of Canada, notably in Quebec and British Columbia; at Atlin (B. C.) large stores of hydromagnesite were found which contained 20 per cent of water, but little lime and other impurities, and which well repaid calcination. Talc and pyrophyllite, likewise of some importance as refractories, occurred in the Transvaal, Newfoundland and Vancouver Island; the quartzose pyrophyllite of the latter island had for some years been quarried and utilized, mixed with clay and shells, as raw material for fireclays. Zirconia, now so much in request, was obtained in the form of impure baddeleyite in Minas Geraes (Brazil), and also in Ceylon, though so far only in small quantities. The chief zirconia material had up to the present been the mineral zircon (67 per cent of ZrO_2), of which large amounts existed in the pegmatite and gem gravels of Ceylon; Zululand, the Federated Malay States and New South Wales also supplied zircon. The monazite sands[1] were another possible cheap source of zircon; the non-magnetic residue of the monazite concentrates from the Travancore coast consisted largely of fine-grained zircon. Mr. Crook exhibited an excellent collection of these minerals from the Imperial Institute, the director of which, he mentioned in concluding, would be glad to give further information.

Dealing with "Refractory Sands," Dr. P. G. H. Boswell, of the Imperial College of Science, said that most of the refractory sands were not true sands in the geological sense, as they frequently contained clay. To a large extent the home resources could no doubt supply refractory sands; but certain desirable properties of those sands were not fully understood yet; geologists did not know what exactly to look for, and much systematic academical research by petrographic and other methods and works investigation were required to find the British analogue to certain foreign materials. Industrial refractory sands might be divided into three classes: (*a*) High silica sands (above 98 per cent of SiO_2); (*b*) high silica and alumina sands (up to 20 per cent of Al_2O_3, silica and little else); (*c*) green sands, for moulding. There was abundance of (*a*), and there were also valuable deposits of (*b*) in this country; but the margins of profit were small and freight and transport were very important factors. As regards (*c*), the best foreign materials had not been equaled yet; it was not fully known what constituted the superiority of the Belgian red and yellow sands, and the Pliocene and Lower Cretaceous should be thoroughly searched in this connection; the Tertiary and Cretaceous deposits of southwest England particularly seemed to deserve attention. Researches were especially desirable as to: mechanical analysis and grading; chemical analysis of each grade; mineral analysis of materials liable to decomposition, in order to decide what constituent formed the bonds; water-holding capacity, for intervals of 10 deg. Cent. up to 110 degrees, and for greater intervals afterward; conductivity; refractoriness; pore space and permeability. A report on British resources of glass-making sands (by Dr. Boswell) was just being published by the Ministry of Munitions; these sands fell under classes (*a*) and (*b*); but the report also referred to refractory sands, the home resources for which were much larger. Admirable work had been done by the Geological Survey, and the number of people working on refractories in this country was astonishing; but there was much wasted haphazard effort and too little co-ordination.

Dr. W. Rosenhain, F.R.S., remarked that Germany and especially America, had been successful in electric-furnace experiments on refractory materials, and the latter country had brought out carborundum, siloxicon, alundum and other products, with which England could hardly compete. As regards zirconia, the future seemed to lie in purified, not in crude zirconia. There were ores with 90 per cent of zirconia. But baddeleyite (density about 4) occurring in Ceylon and Brazil, was much more abundant, and though it contained only about 75 per cent of ZrO_2, 13 of SiO_2, 1 of TiO_2, 3.5 of Fe_2O_3, 2.2 of CaO, 1.6 MgO and 1.1 Al_2O_3, it appeared up to 1,650 deg. Cent. to be as refractory as pure zirconia, so far as his laboratory tests went. The difficulty was that zirconia was apt to form carbide, and that the product had to be baked at the highest temperatures, because it was a very bad conductor of heat and went on shrinking for a long time. The iron could partly be extracted from the brown mineral, which then turned white with the aid of sulphuric acid; he had used the purified mineral in his optical glass researches. As regards the liability to crack, that always depended upon two sets of properties: (1) The temperature gradient set up, a question of conductivity, specific heat and density of the material; (2) coefficient of expansion, elasticity modulus and tensile strength. A given rise of temperature per millimeter depth would give rise to a certain expansion, and if this expansion were resisted by the non-expansion of the adjacent layers, a tensile stress was set up in the latter equal to the tensile stress that would be required to produce the same expansion by elastic deformation; when this stress was greater than the tensile strength of the material, a crack would result. This view was based upon work done on glass, described in Hovestadt's book. The tensile strength of non-metallic bodies (glass, fireclay, etc.) was always very low, however, though their compression strength was considerable. A body which would not crack with sudden temperature changes should have high specific heat and density, high tensile strength and elastic modulus, but low thermal conductivity and expansion coefficient.

Prof. T. Turner, of the University of Birmingham, remarked that they had hoped to have a refractory department, as at Sheffield. Porosity was very important, and might be measured by drawing air through the material. He had also experimented on volume changes in coke ovens. Dr. Mellor's remark that round grain did not give the closest packing was only correct for spheres all of one size; with small and larger grains alternating a very close packing could be secured.

[1] Monazites are phosphates of the rare earths, the raw material for incandescent mantles.

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